THE WATER QUALITY OF LAKE TEMAGAMI

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Ministry of the Environment
Ontario

The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

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OF

LAKE TEMAGAMI

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FRONTISPIECE

TEMAGAMI

Far in the Northwest beyond the lines
That turn the rivers eastward to the sea,
Set with a thousand islands, crowned with pines,
Lies the deep water, wild Temagami.
Wild for the hunter's roving, and the use
Of trappers in its dark and trackless vales,
Wild with the trampling of the giant moose,
And the weird majic of old Indian tales.
All day with steady paddles toward the west
Our heavy-laden long canoe we pressed,
All day we saw the thunder-travelled sky
Purpled with storm in many a trailing tress,
And saw at eve the broken sunset die
In crimson on the silent wilderness.

Archibald Lampman.

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SUMMARY AND CONCLUSIONS

The results of investigations carried out in the summer of 1972 indicate that, with the exception of the Northeast Arm near the Village of Temagami, Lake Temagami is extremely oligotrophic in status, exhibiting generally high water quality. Water quality in the Northeast Arm adjacent to Temagami was found to be grossly impaired due to inputs from Temagami and the intensive cottage developments in this area.

No evidence of present acidification of Lake Temagami owing to airborne contaminants from the mineral smelting industry at Sudbury was found.

Concentrations of heavy metals in Lake Temagami, particularly cadmium and zinc, are of concern since the limited data available suggests that some of these levels approach the concentrations considered to exert a negative impact on fish.

Existing eutrophication problems and the known susceptability of Lake Temagami to adverse changes as a result of nutrient enrichment are evidence of a major constraint to future shoreline development using existing nutrient-conveying septic tank-tile bed systems.

RECOMMENDATIONS AND PLANS FOR FURTHER ACTION

Based on the interpretation of the results of this study it is recommended that:

1. Caution be exercised in designing future shoreline development to ensure that sewage disposal systems meet the standards of the Ministry of the Environment.
2. An acceptable method of sewage disposal for the Village of Temagami and vicinity be designed and implemented as soon as practicable.
3. The chlorophyll a - Secchi disc "self-help" and pH monitoring programmes be continued as planned.
4. Additional data be collected on the concentrations of heavy metals in Lake Temagami and a programme be initiated to determine the concentration of metals in fish flesh.
5. A cottage survey be undertaken as soon as practicable to evaluate the efficiency of individual sewage disposal systems.

1.0 INTRODUCTION

1.1 Purpose and Scope

The Ministry of Natural Resources published a management plan for Lake Temagami (Department of Lands and Forests, 1971)which provided for a substantial increase in the number of cottages on the lake. It was a concern of the Temagami Lakes Association and the Ministry of the Environment that the present water quality should be evaluated before any additional development was initiated. Also, there was some concern that the water quality and fishery of Lake Temagami were declining due to possible acidification by atmosphericallv conveyed sulphuric acid from the sulphide ore smelting industry located at Sudbury, some 60 miles to the southwest (see Bangay, 1973)

To define water quality in Lake Temagami, an intensive sampling programme was carried out during the summer of 1972 with emphasis on determining the trophic status of the lake and the potential effects of future development. The status of the lake with regard to present and potential acidification by air-borne contaminants was also investigated.

The study was carried out in three phases:

1. From May 31 to September 19, Secchi disc readings and chlorophyll a samples were taken at weekly intervals by staff of the Ministry of Natural Resources.
2. During the period August 11 to 31, an intensive water quality investigation was carried out by staff of the Ministry of the Environment.

3. From July 22 to September 2, an extensive sampling programme with emphasis on pH monitoring was carried out by members of the Temagami Lakes Association (T.L.A.) and Temagami Region Studies Institute (T.R.S.I.*).

1.2 Description of the Study Area

Lake Temagami (47°00'M' 80°00'W) is a large lake in the Precambrian Shield area of Ontario occupying portions of the Townships of Canton, LeRoche, Belfast, Scholes, Clement, Aston, Cynthia, Joan, Phyllis, Vogt, Briggs, Yates and Strathcona in the North Bay Forest District. The lake forms part of the Sturgeon River drainage basin flowing to Lake Nipissing. Lake Anima Nipissing, to the north, forms the headwaters of Lake Temagami and outflow is via the Temagami River to the south.

Lake Temagami is an extremely irregular body of water having numerous bays and inlets and several long arms. The mainland shoreline has been measured at 600 km (370 miles) and an additional 320 km (200 miles) of shoreline is provided by over 1400 islands. Total water area is approximately 20,200 ha (50,000 acres) and the majority of the lake is quite deep (maximum depth - 106 m [350 feet], mean depth - 18 m [60 feet]). A summary of morphometric data for Lake Temagami is provided in Table 1.2.1. A detailed description of the local geography including soils, rocks, forests and climate is provided in the Lake Temagami Plan for Recreational Development (Department of Lands and Forests, 1971).

* *At the time of this survey the T.R.S.I. was being formed with the expressed purpose of directing and assisting research in the Temagami area. Since cottagers assisting in the work were members of the T.L.A. and/or the T.R.S.I. both organizations are cited hereafter although in essence only a small core of interested cottagers participated.*

TABLE 1.2.1

MORPHOLOGICAL DATA FOR LAKE TEMAGAMI

	BRITISH UNITS	METRIC UNITS
Surface Area	50,000 acres	2.02×10^8 metres^2
Maximum Depth	350 feet	1.06×10^2 metres
Mean Depth	60 feet	1.8×10 metres
Volume	890,000 million gallons	4.0×10^9 metres^3
Perimeter		
Mainland	370 miles	600×10^2 kilometres
Islands	200 miles	3.20×10^2 kilometres

During this study, sampling was carried out at 24 locations on Lake Temagami. Figure 1.2.1 is a map of the lake showing the locations of sampling stations. A description of individual station locations is provided in Table 1.2.2.

TABLE 1.2.2

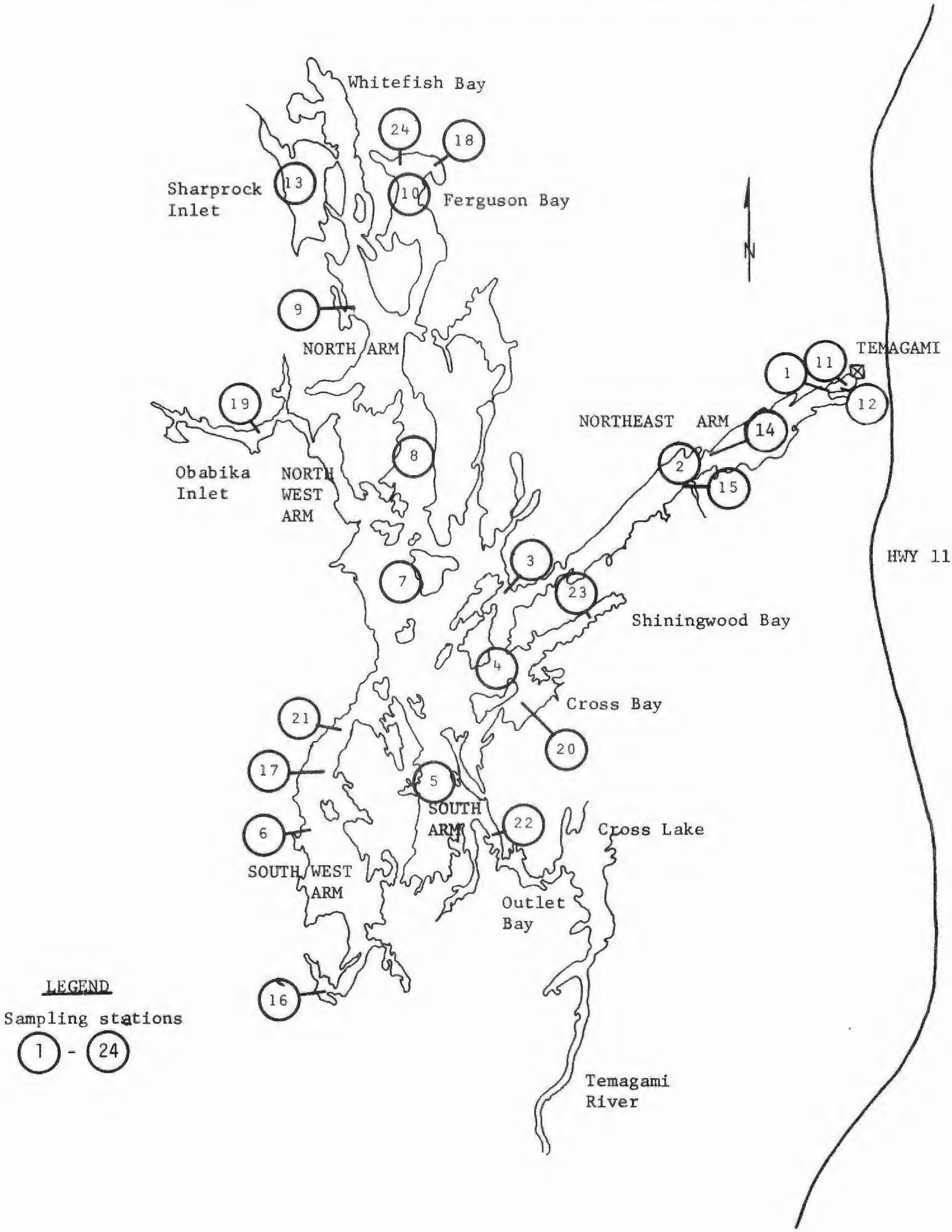
LOCATIONS OF SAMPLING STATIONS - LAKE TEMAGAMI STUDY, 1972

Station	Location
1	Northeast Arm near Bell Island
2	Northeast Arm south of Axe Narrows
3	Mouth of Northeast Arm at Mattagami Point
4	Mouth of Shiningwood Bay
5	Mouth of South Arm
6	Southwest Arm near Camp White Bear

Station	Location
7	Just West of Bear Island
8	North Arm near Rabbitnose Island
9	North Arm near Racoon Point
10	West side of Ferguson Bay
11	Just offshore from O.P.P. buildings in Temagami
12	Just offshore from Amich Lodge, near Temagami
13	Sharp Rock Inlet off Windshift Canoe Camp
14	Mouth of Tetapaga River
15	Mouth of South Tetapaga River
16	Baie Jeanne
17	Southwest Arm at mouth of creek flowing from Gull Lake
18	Ferguson Bay off mouth of Anima Nipissing River
19	Obabika Inlet
20	Cross Bay
21	Mouth of Southwest Arm
22	Outlet Bay
23	Shiningwood Bay
24	Ferguson Bay off mouth of Eagle River

NOTE:
1. Stations 1 to 10 sampled by Ministry of Natural Resources, Ministry of Environment, Temagami Lakes Association and T.R.S.I.
2. Stations 11 and 12 sampled by Ministry of Environment only.
3. Station 13 sampled by Ministry of Environment, Temagami Lakes Association and T.R.S.I.
4. Stations 14 to 24 sampled by Temagami Lakes Association and T.R.S.I. only.

FIGURE 1.2.1 - MAP OF LAKE TEMAGAMI SHOWING THE LOCATION OF SAMPLING STATIONS



1.3 Present Development and Uses

At present, the major use of Lake Temagami is as a high quality outdoor recreation area. The lake supports both warm-water (bass, walleye, northern pike) and cold-water (lake trout, whitefish) fisheries and has long been famous for the quality of its angling. Fishing pressure remains heavy in both summer and winter (Jorgensen, 1973). The Ministry of Natural Resources is concerned that over exploitation of the lake trout fishery may be occurring.

Cottage development is restricted almost exclusively to islands - of its 600 km (370 miles) of mainland shoreline only 8 km (5 miles) are privately owned. However, of the 320 km (200 miles) of shoreline on islands, 91 have been disposed of for cottage and resort development. Based on data from the Lake Temagami Plan for Recreational Development, recreational use of Lake Temagami at established facilities amounted to 268,267 vacation days in 1968. This figure is exclusive of visitors to Finlayson Provincial Park and casual visitors who provide their own services. The lake serves as a major staging area for canoe-tripping. Although the recreational activity is strongly biased toward the ice-free period, some portions of Lake Temagami receive relatively heavy winter use by snowmobilers.

A significant portion of the islands and mainland is under long term mining leases. At present, Sherman Mine (iron ore) near the Village of Temagami is the only active mine in the area. A biological survey of waters receiving wastes from Sherman Mine was completed in 1972 and a report is in press (Conroy and Keller,

1974). Temagami Island Mine, a small base-metal mine on Temagami Island, has recently ceased operation.

Six operators presently hold timber licences in the vicinity of Lake Temagami. Wm. Milne and Sons Limited is the only licencee using the lake waters for the transportation of logs.

Lake Temagami is the source of drinking water for almost all cottages, commercial camps, residents of Bear Island and the Village of Temagami.

The Village of Temagami is the major settlement in the vicinity of Lake Temagami. At present, most of the sewage generated in the village is disposed of by individual septic tank-tile bed systems. Surveys by the Timiskaming Health Unit (1967-68) and O.W.R.C. (1967) revealed that many of the existing sanitary facilities (47%) were malfunctioning to the extent that storm sewers and ditches flowing to Portage Bay were found to contain domestic sewage. At that time Portage Bay, adjacent to the community, was unsafe for swimming.

A summary of population centres in the area is provided in Table 1.3.1.

TABLE 1.3.1

POPULATION CENTRES IN THE VICINITY OF LAKE TEMAGAMI

Location	Population
Village of Temagami	900
New Temagami Townsite	200
Milne Townsite (north shore of Link Lake)	100
Gillies Townsite (Snake Island Lake)	75
2 trailer parks (Link Lake and Hwy. 11 north of Goward)	125
Bear Island Indian Reserve	100-150

NOTE: Table 1.3.1 reproduced from Lake Temagami Plan for Recreational Development, 1971.

2.0 METHODS

2.1 Station Selection

In this study, emphasis was placed on selecting stations representative of general lake-water conditions. Sampling locations to be used in trophic state determination were selected by applying the following criteria:

1. A depth of 10-40 metres.
2. A location not obviously influenced by local currents or excessive wave action.
3. An area which would not be interfered with by recreational activity.
4. An area not obviously influenced by shore factors or inflows to the lake.

Additional sampling stations were located in specific areas of concern throughout the lake.

2.2 General Water Chemistry

Water samples for chemical analysis were collected by pumping from specified depths into sterilized glass bottles. Two 1 litre bottles were collected per depth and two depths (1 metre below surface and 1 metre above bottom) were sampled at each station.

Water samples for metals analyses were collected in polyethylene bottles and were acidified with sufficient nitric acid to prevent the adsorption of metallic ions onto the walls of the container.

Samples were transported to the Ministry of the Environment laboratory in Toronto for analyses, including:

calcium	magnesium	sodium
potassium	silica	sulphate
chloride	nitrite	nitrate
ammonia	total Kjeldahl	phosphorus
hardness	alkalinity	carbon

The metal analyses included:

copper	zinc	nickel
cadmium	cobalt	arsenic
iron		

2.3 pH Monitoring

During the 1972 survey, pH samples were collected at various depths throughout the water column. Samples were taken by pumping water from the specified depths through a 5/8" diameter 'garden hose' with a 12 volt D.C. centrifugal pump.

Wherever possible, pH measurements were taken in the field immediately after collection. Samples not measured immediately were transported to the field laboratory in a portable cooler and were measured within four hours of the time of collection. pH meters employed in this study included a Corning digital 109, an IL model 175 and a Criterion model pHM-71. The recorded pH represented an average of three separate measurements at each depth per location.

2.4 Precipitation Chemistry

In 1970 a programme was initiated to measure the composition of bulk precipitation in Ontario. Responsibility for the project was shared by McMaster University, Hamilton and the Ministry of the Environment.

As part of this programme a bulk precipitation collector (rain and snow) was installed on the roof of the Ministry of Natural Resources warehouse in Temagami in June, 1970, and has operated continuously since that time. Precipitation samples are removed from the collector at monthly intervals and are analysed for numerous parameters including pH and sulphates.

Precipitation data included in this report are taken from the results of the above mentioned study with the expressed permission of Kramer, 1973.

2.5 Chlorophyll *a* and Secchi Disc

At weekly intervals throughout the summer, stations 1 to 10 were sampled for chlorophyll *a* concentrations and Secchi disc transparency depths.

The Secchi disc depth provides a measure of the degree of light penetration in water. Readings are taken by lowering the disc (20 cm in diameter with alternating black and white quadrants) to the depth at which it just disappears. This depth is recorded and the disc is raised to the depth at which it reappears and that depth is recorded. The point halfway between these two readings is the Secchi disc transparency depth.

Chlorophyll *a* samples were collected as composites through the euphotic zone (zone of significant light penetration - taken as twice the Secchi disc reading). A composite sample is collected by lowering a 1 litre glass bottle in a weighted sampler to a depth

equal to twice the Secchi disc reading and then retrieving it at such a rate to allow complete filling as it reaches the surface. The object is to collect water equally from all portions of the sampling column. Figures 2.5.1 and 2.5.2 present schematic representations of the methology of composite sampling and the composite sampler respectively.

Samples for chlorophyll a analysis were immediately stabilized with sufficient magnesium carbonate solution (2% volume to volume ratio) to elevate the pH and retard the breakdown of chlorophyll a during transportation. Samples were shipped to Toronto and analysed in the Ministry of the Environment Laboratory within 48 hours of the time of collection.

2.6 Temperature and Dissolved Oxygen

Temperature profiles and dissolved oxygen depth distributions were investigated at stations 1 to 13. Samples were pumped from specified depths with a 12 volt centrifugal pump and were analyzed at the time of collection.

Temperatures were measured in degrees centigrade with a mercury thermometer. Dissolved oxygen was determined by the modified Winkler technique provided in kit form by Hach Chemicals or with an E.I.L. model 1520 dissolved oxygen meter.

FIGURE 2.5.1 -COMPOSITE SAMPLING PROCEDURE

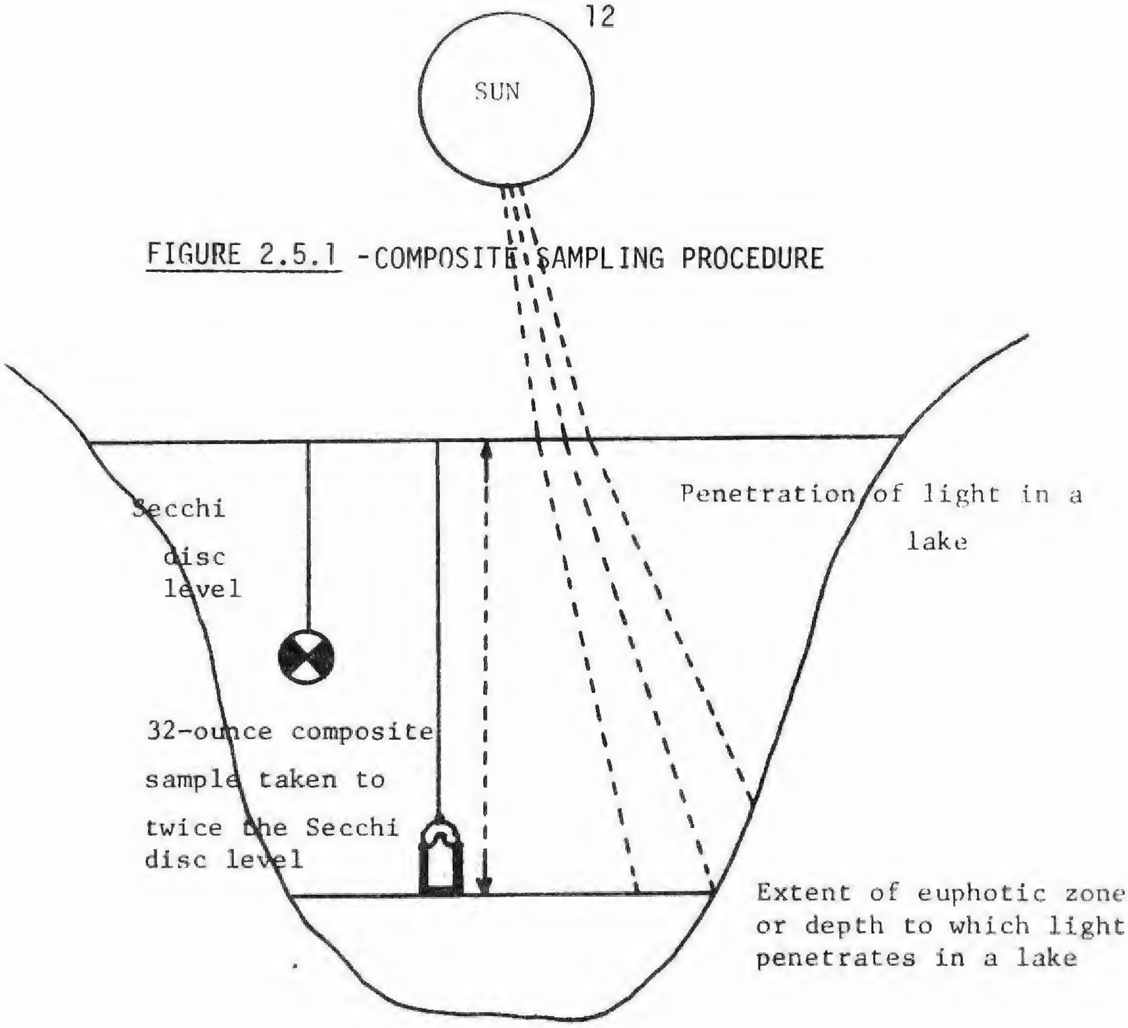
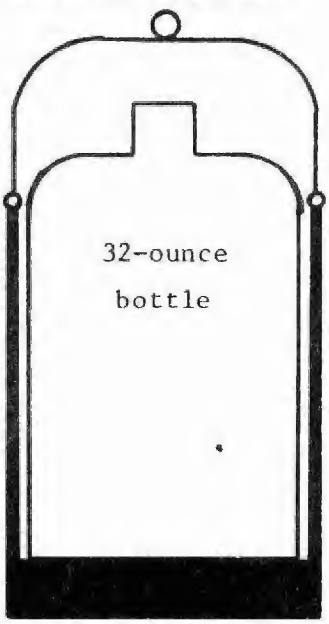


FIGURE 2.2.2

A COMPOSITE SAMPLER



Composite sampler with
lead-filled bottom

3.0 RESULTS

3.1 General Water Chemistry

The results of chemical analyses of water from the open lake stations on Lake Temagami are provided in Table V of Appendix B. A summary of mean concentrations of selected chemical variables is provided in Table 3.1.1.

Alkalinity, Hardness and Conductivity

Alkalinity, a measure of a lake's acid buffering capacity, ranged from a mean value of 4.0 mg l^{-1} at station 13 to a mean value of 25 mg l^{-1} at station 12. Stations 1, 2, 11 and 12 in the North-east Arm exhibited the highest alkalinities (mean values of 20, 16, 23 and 25 mg l^{-1} respectively). Station 13 showed the lowest alkalinity (4 mg l^{-1}) and the remaining stations had mean alkalinities ranging from 10 to 13 mg l^{-1}.

Hardness followed a pattern similar to that of alkalinity in that values were highest at stations 1, 2, 11 and 12 (means of 42, 43.5, 36 and 39.5 mg l^{-1} respectively). Station 4 also showed a relatively high hardness (39 mg l^{-1}) while the remaining stations had mean hardness values ranging from 22.5 to 32 mg l^{-1}.

Conductivity, (a measure of the ionic strength of water) was highest at stations 1, 2, 11 and 12 (means of 94, 85, 105, 128 μmho cm^{-1} respectively) while station 13 exhibited the lowest conductivity (40 μmho cm^{-1}). The remaining stations had mean conductivity values between 56 and 65 μmho cm^{-1}. The results of conductivity measurements are provided in Table II of Appendix B.

TABLE 3.1.1

MEAN VALUES OF SELECTED CHEMICAL VARIABLES

LAKE TEMAGAMI, 1972

PARAMETER	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Ca	12	11.5	8.5	9	8.5	11	7.5	9	8	8	12	13	5
Na	3	2	1	1	1	1	1.5	1	1	1	3.5	5	1
K	.8	.6	.3	.3	.3	.1	.2	.3	.2	.2	.7	.6	.2
SiO_2	.8	.8	1.0	1.2	1.7	1.8	1.0	1.4	1.5	1.7	1.2	1.6	1.3
SO_4	18	17	15	15	15	15	16	22	18	15	19	16	13
NH_3	.027	.020	.030	.017	.015	.015	.017	.015	.017	.020	.037	.107	.030
Kjeldahl	.36	.20	.24	.18	.19	.19	.22	.23	.17	.20	.34	.28	.16
NO_2	.004	.003	.003	.003	.003	.003	.004	.003	.003	.003	.007	.009	.003
NO_3	.01	.03	.04	.03	.04	.05	.03	.05	.04	.05	.04	.11	.02
P (total)	.034	.007	.010	.008	.007	.014	.012	.013	.011	.014	.034	.056	.006
P (soluble)	.006	.001	.001	.002	.002	.005	.003	.005	.003	.002	.007	.015	.003
Hardness	42	43.5	31.5	39	27.5	22.5	25.5	30	32	30.5	36	39.5	-
Alkalinity	20	16	12	12.5	12	10.0	12	13	12	11	23	25	4
C (organic)	7	7	7.5	6.5	6	6	6	5	4	2	7	9	-
C (inorganic)	4.5	3.5	2.5	2	2	2.5	2	3	3	2	3	5	-

all values expressed in mg l^{-1}

note: data collected by Ministry of the Environment

Major Cations

Distributions of calcium, sodium and potassium followed similar patterns in that the highest concentrations occurred at stations 1, 2, 11 and 12 in the Northeast Arm. Station 6 showed a somewhat elevated calcium concentration; however, sodium and potassium levels remained low. Lowest values generally occurred at station 13 (Sharp Rock Inlet). A summary of the range in concentrations of the major cations in areas of the lake is provided in Table 3.1.2 below.

TABLE 3.1.2

RANGE IN CONCENTRATION OF MAJOR CATIONS

LAKE TEMAGAMI, 1972

	Northeast Arm	Sharp Rock Inlet	Other Stations
Calcium	11.5 to 13	5	8-11
Potassium	.6 to .8	.2	.1 to .3
Sodium	2 to 5	1-1.5	1

Major Anions

The major anion in Lake Temagami was sulphate with a mean concentration ranging from 13 to 22 mg l^{-1}. The highest sulphate concentrations occurred at stations 1, 2, 8, 9 and 11 (means of 18, 17, 22, 18 and 19 mg l^{-1} respectively) while the lowest sulphate concentration was noted at station 13 (13 mg l^{-1}). Other stations exhibited mean sulphate concentrations between 15 and 16 mg l^{-1}.

Silica was low in Lake Temagami with mean concentrations ranging from .8 to 1.7 mg l^{-1}. No pattern was evident in the variation of silica concentrations.

Metals

The results of chemical analyses for total copper, zinc, nickel, cadmium, cobalt, arsenic and iron for the sampling stations 1 through 13 are provided in Table VI of Appendix B with separate entries for surface and bottom samples.

Any interpretation of the heavy metal data is difficult since the same lower detection limit was not used by the laboratory in all samples. Nevertheless, a biased mean and the range in concentration are provided in Table 3.1.3 below. The calculation of the mean was biased by excluding 'less-than' values as well as 0.0 values. No significant difference was found between surface samples and bottom samples and indeed, the variability between stations can not easily be accounted for by normal lake processes.

TABLE 3.1.3

MEAN AND RANGE (biased) OF SELECTED METAL CONCENTRATIONS ($\mu g\ l^{-1}$) FOR LAKE TEMAGAMI

	Cobalt	Copper	Zinc	Nickel	Cadmium	Iron
Minimum	1	<1	<1	<1	<1	5
Mean	3.5(4)	9.0(9)*	55.8(38)	13.6(36)	54.6(11)	147.9(30)
Maximum	6	1200	670	73	200	1300

(11) Sample Size

* Excluding the value of 1200 $\mu g\ l^{-1}$

3.2 pH Monitoring

The results of pH analyses for Lake Temagami are provided in Tables II and III of Appendix B.

The lowest pH detected during the study was 5.5 (bottom waters at station 13 on August 31st), while the highest pH (8.3) was recorded from the surface waters at station 12 on August 18th. This range represents a thousand fold difference in the hydrogen ion concentration of the lake. Notwithstanding this large range in pH the mean values for the sampling stations with all values considered showed only a narrow range and normally were near neutral. The grand mean for 24 sampling stations was 6.9 with a range of 6.0 to 7.4. This information is provided in Table 3.2.1 below.

TABLE 3.2.1

MEAN pH VALUES, LAKE TEMAGAMI, 1972

Station	Mean pH	Station	Mean pH
1	7.1	13	6.0
2	7.2	14	7.4
3	6.9	15	6.9
4	6.9	16	6.7
5	6.8	17	6.6
6	6.6	18	7.0
7	7.0	19	6.3
8	6.9	20	7.0
9	6.8	21	7.0
10	6.7	22	7.2
11	6.9	23	6.9
12	7.4	24	7.0
	Grand Mean	6.9	
	Range	6.0-7.4	

NOTE: Ministry of the Environment, Temagami Lakes Association and T.R.S.I. data were used in calculating mean values.

3.3 Precipitation Chemistry

Since the results of the precipitation monitoring programme are as yet preliminary no attempt is made to present this data in detail. Preliminary data on pH and sulphate concentrations and a limited discussion are provided in Section 4.1.

3.4 Chlorophyll *a* and Secchi disc

The results of chlorophyll *a* and Secchi disc sampling on Lake Temagami for the period May 31 to September 19, 1972, are provided in Table I of Appendix B. Maximum, minimum and mean chlorophyll *a* concentrations and Secchi disc readings are summarized in Table 3.4.1 below.

TABLE 3.4.1

MAXIMUM, MINIMUM AND MEAN CHLOROPHYLL *a* CONCENTRATIONS AND SECCHI DISC READINGS

LAKE TEMAGAMI, MAY 31 TO SEPTEMBER 19, 1972

STATION	SECCHI DISC (m)			CHLOROPHYLL a ($\mu g\ l^{-1}$)		
	MAXIMUM	MINIMUM	MEAN	MAXIMUM	MINIMUM	MEAN
1	8.5	4.9	6.5	2.4	0.5	1.3
2	9.1	5.2	6.9	2.3	0.4	1.2
3	9.7	6.1	7.6	1.9	0.5	1.1
4	9.7	4.6	7.7	2.0	0.4	1.1
5	10.7	6.4	8.3	1.6	0.4	0.9
6	9.4	4.9	7.4	1.9	0.5	1.2
7	11.0	6.1	8.0	1.6	0.4	1.0
8	11.9	6.4	8.4	1.5	0.4	0.9
9	11.9	6.1	8.2	1.4	0.4	1.0
10	10.1	5.5	7.9	1.5	0.5	0.9
OVERALL	11.9	4.6	7.7	2.4	0.4	1.1

The mean concentration of chlorophyll *a* varied from 0.9 to 1.3 $\mu g\ l^{-1}$ between stations with an overall mean of 1.1 $\mu g\ l^{-1}$. Stations 5, 8 and 10 exhibited the lowest mean chlorophyll *a* concentrations (0.9 $\mu g\ l^{-1}$) while stations 1, 2 and 6 showed the highest mean chlorophyll *a* concentrations (1.2 - 1.3 $\mu g\ l^{-1}$).

Secchi disc readings corresponded directly to chlorophyll *a* concentrations in that the stations exhibiting the lowest chlorophyll concentrations (5, 8 and 10) had higher Secchi disc readings (8.3, 8.4 and 7.9 metres respectively) than did the stations with the highest chlorophyll concentrations (1, 2 and 6 - mean Secchi disc readings of 6.5, 6.9 and 7.4 metres respectively).

As indicated in Table 3.4.1, mean Secchi disc values for the sampling period ranged from 6.5 to 8.4 metres. Single Secchi disc readings taken at two additional stations (designated 11 and 12) in Portage Bay of the Northeast Arm on August 18 were 3.8 and 4.2 metres respectively - much shallower than the readings at all other lake stations at that time.

3.5 Temperature and Dissolved Oxygen

Temperature

Temperature - depth profiles based on the temperature data recorded in Table IV of Appendix B are provided in Figure 3.5.1.

Although surface temperatures remained relatively constant (17 to 20°C), temperature-depth profiles, as shown in Figure 3.3.1 varied considerably between areas of the lake. Some stations, such as station 1, showed well defined thermoclines on all dates while others showed evidence of destruction of the thermocline at certain periods (see stations 6 & 7 on August 17th). Additionally, some

FIGURE 3.5.1 - TEMPERATURE-DEPTH PROFILES, LAKE TEMAGAMI, 1972

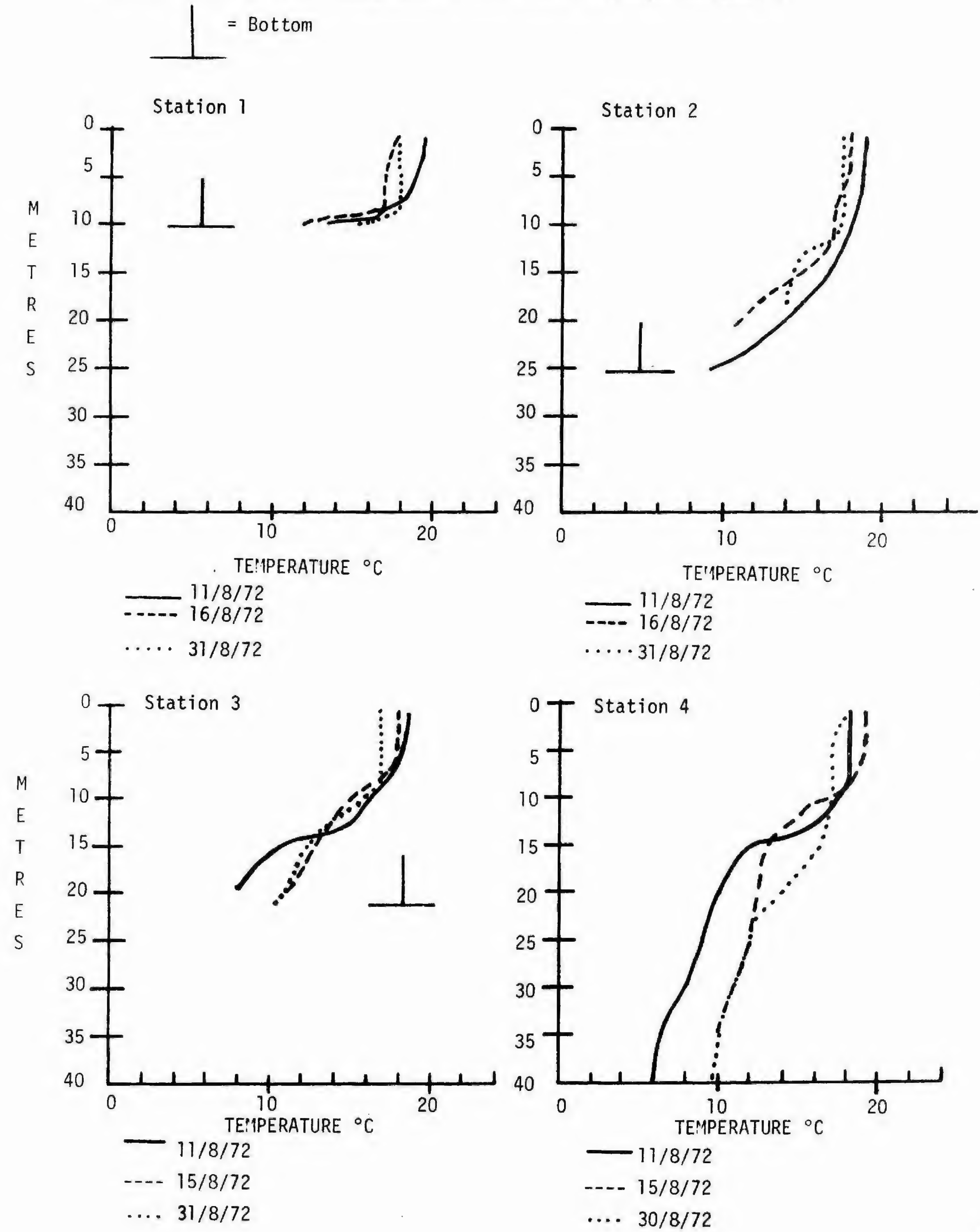


FIGURE 3.5.1 continued

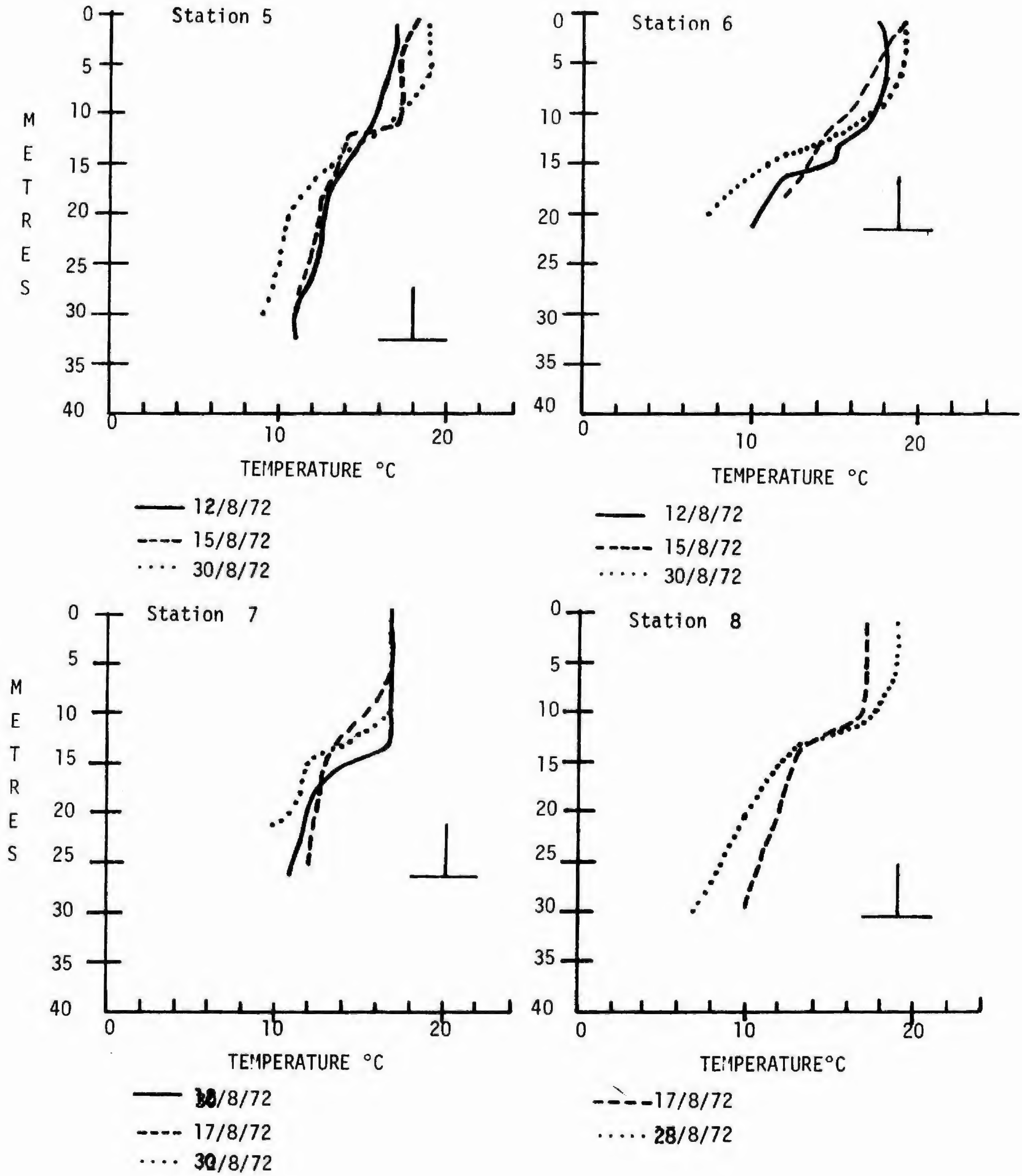


FIGURE 3.5.1 continued

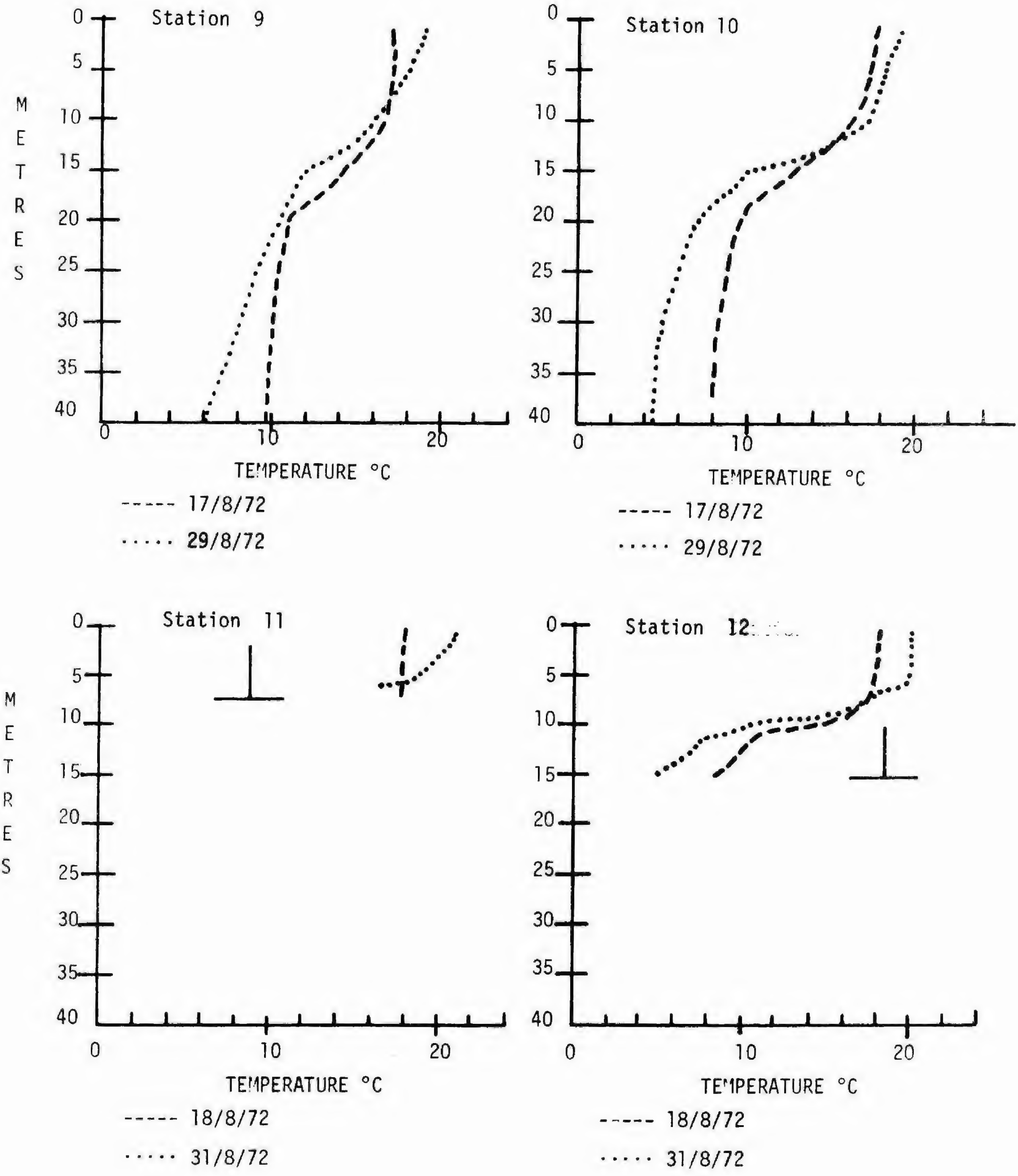
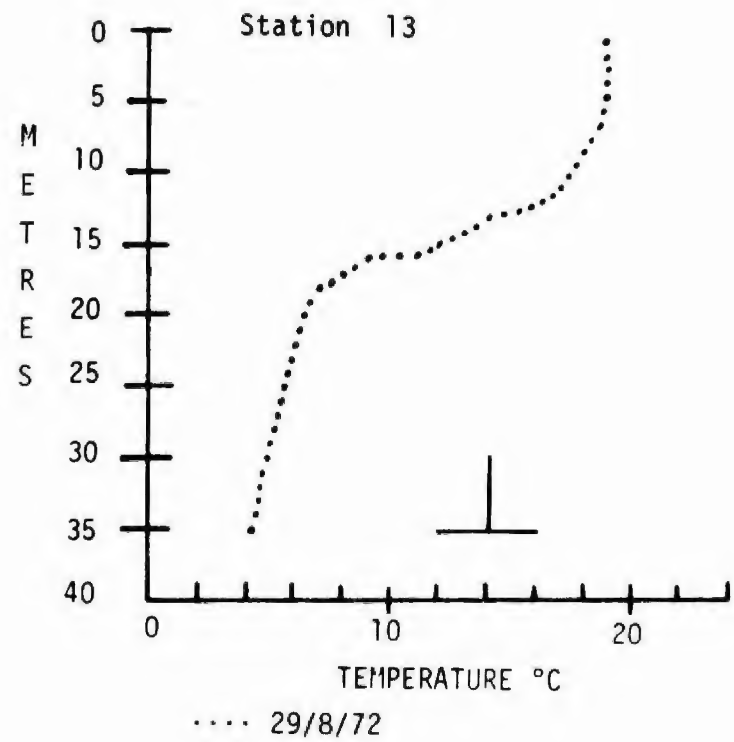
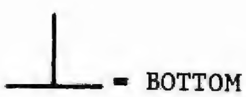


FIGURE 3.5.1 continued





areas did not show meaningful thermal stratification on any sampling date during the various investigations in August (e.g. station 3). In general, in areas where thermal stratification was found, the boundaries of the thermocline formed between 10 and 16 metres. Significant hypolimetic volumes were present in areas with depths greater than 18 metres such as stations 8 and 13, while in shallower zones such as stations 1 and 11 the hypolimnia were virtually absent.

Dissolved Oxygen

Dissolved oxygen profiles based on the data presented in Table IV of Appendix B are provided in Figure 3.5.2.

The distribution of dissolved oxygen with depth was affected by the nature of the temperature distribution and the depth. At stations 1 and 12 where strong thermoclines were recorded and the volume of the hypolimnion was minimal, strong clinograde dissolved oxygen curves were present (i.e. strongly diminishing dissolved oxygen as a function of depth) while in areas where the volume of the hypolimnion was large and/or the thermocline was indistinct such as at stations 5 and 8, an orthograde oxygen curve was present (i.e. essentially non-diminishing with depth).

Positive heterograde (a midwater oxygen pulse) and negative heterograde (a midwater oxygen deficiency) curves were present at stations 3 and 13 respectively. The lowest dissolved oxygen concentrations were recorded in the bottom waters of station 1 and 12 where strong clinograde oxygen profiles were present. These minimums on at least one occassion were 1 mg l^{-1} or less and on most occasions were less than 3 mg l^{-1}. These concentrations are below the levels considered necessary for the survival of fish.

FIGURE 3.5.2
DISSOLVED OXYGEN-DEPTH DISTRIBUTIONS
LAKE TEMAGAMI, 1972

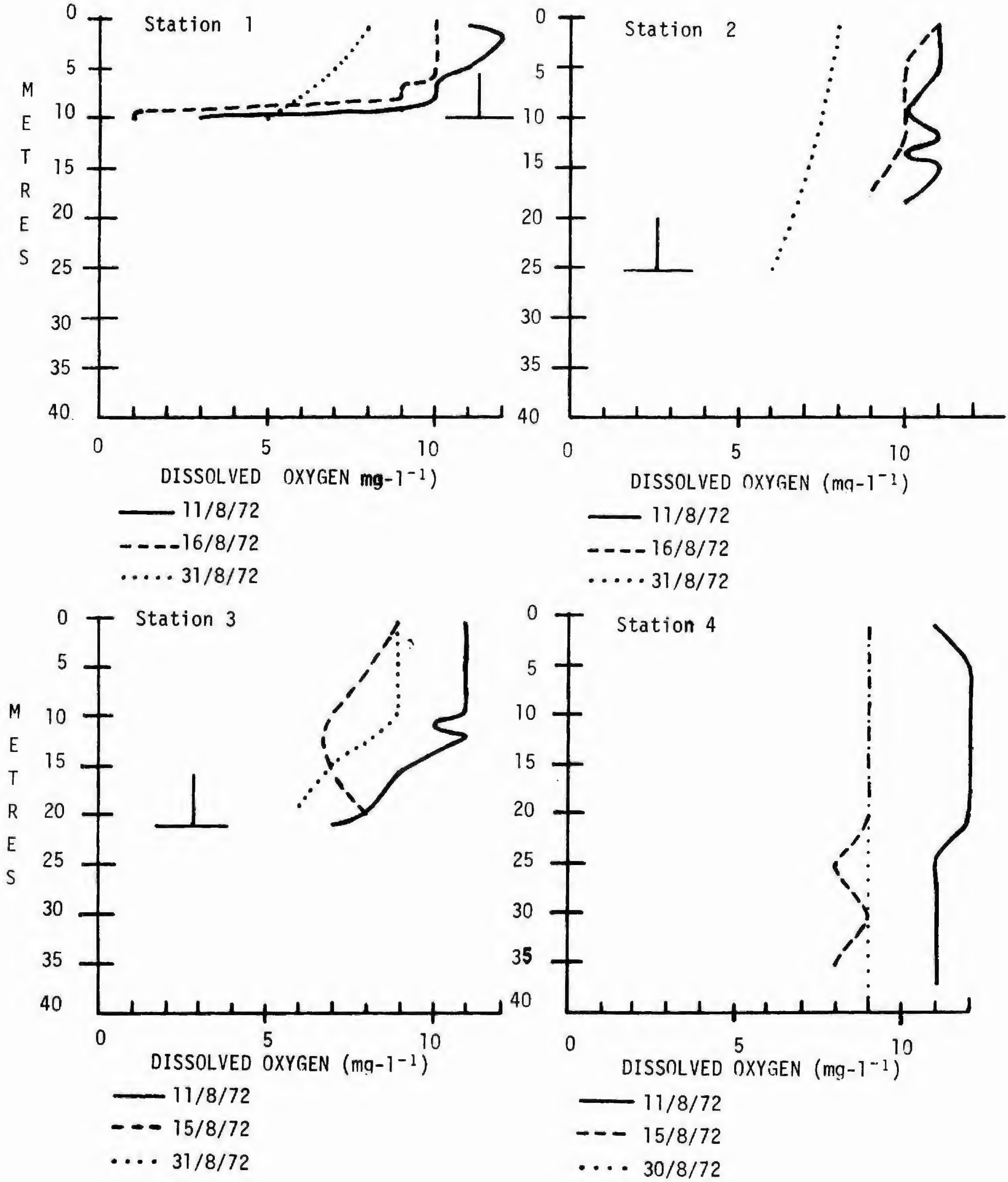
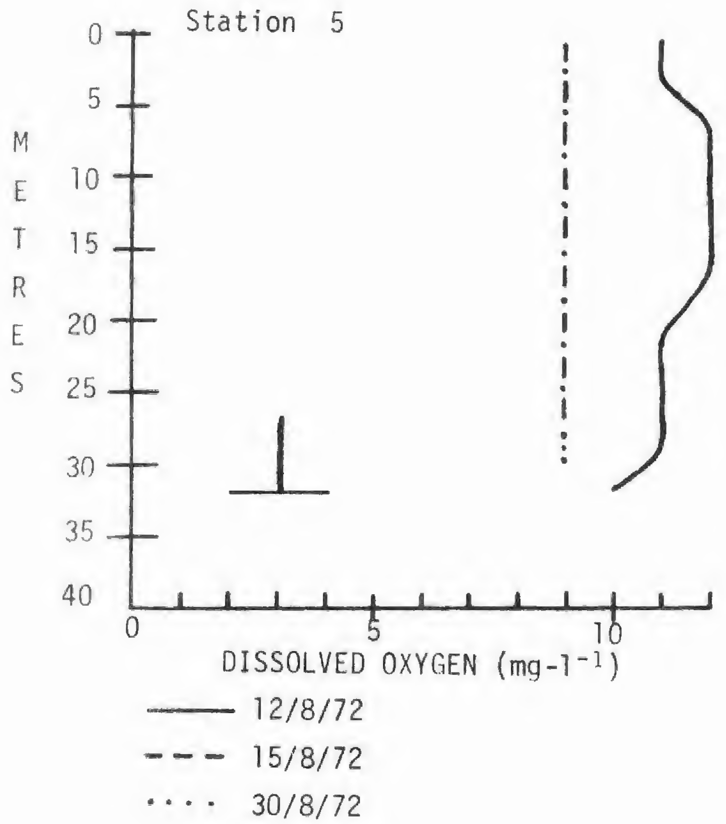
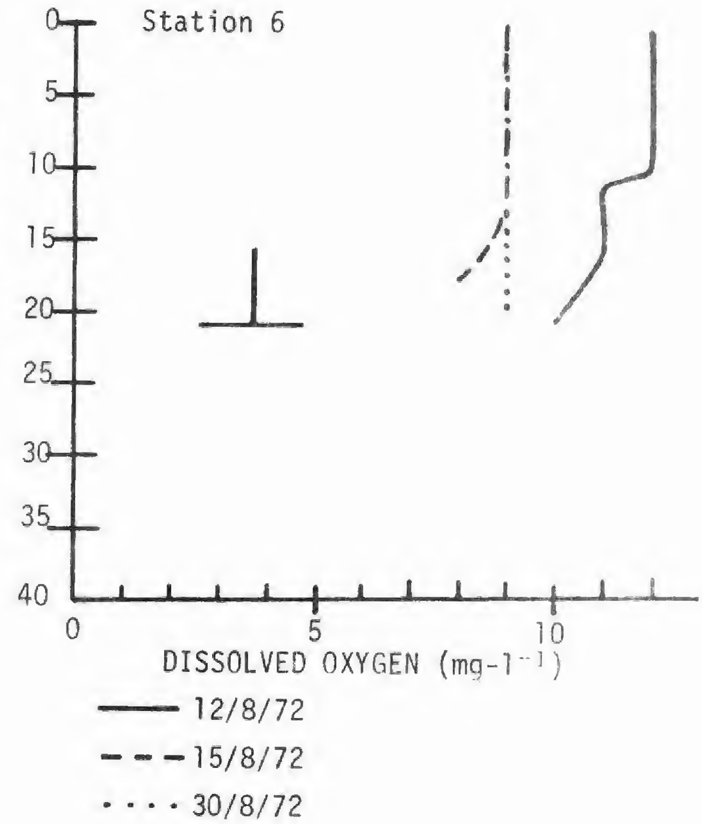
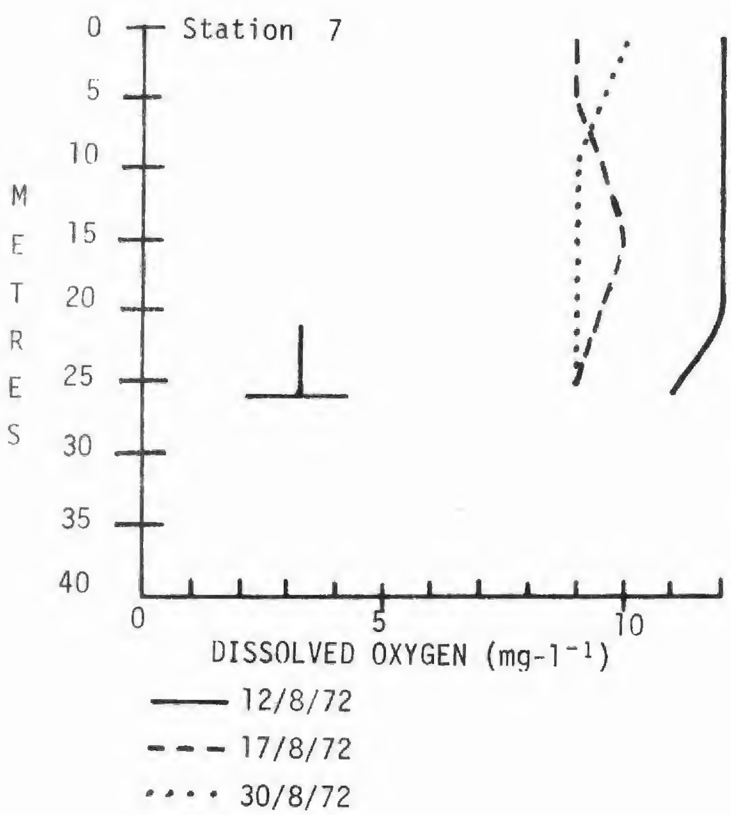


FIGURE 3.5.2 - continued







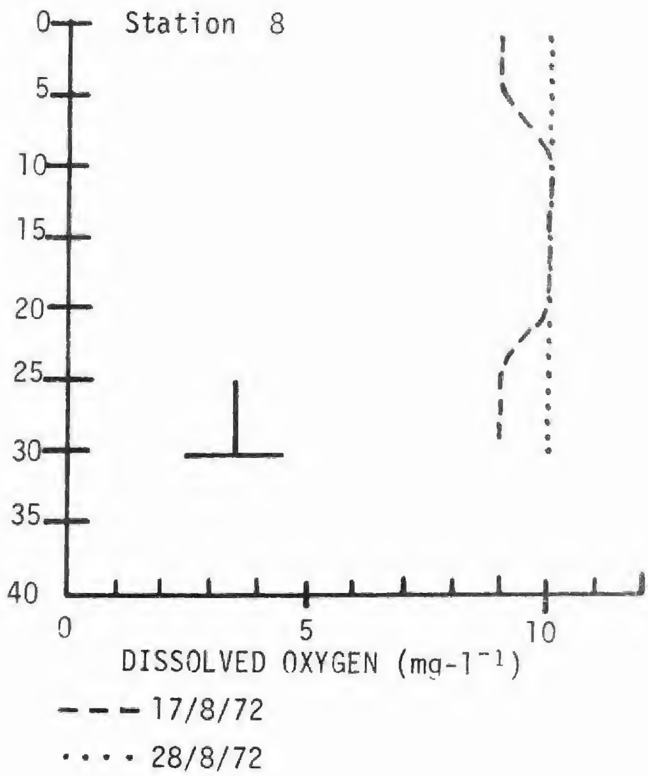


FIGURE 3.5.2 - continued

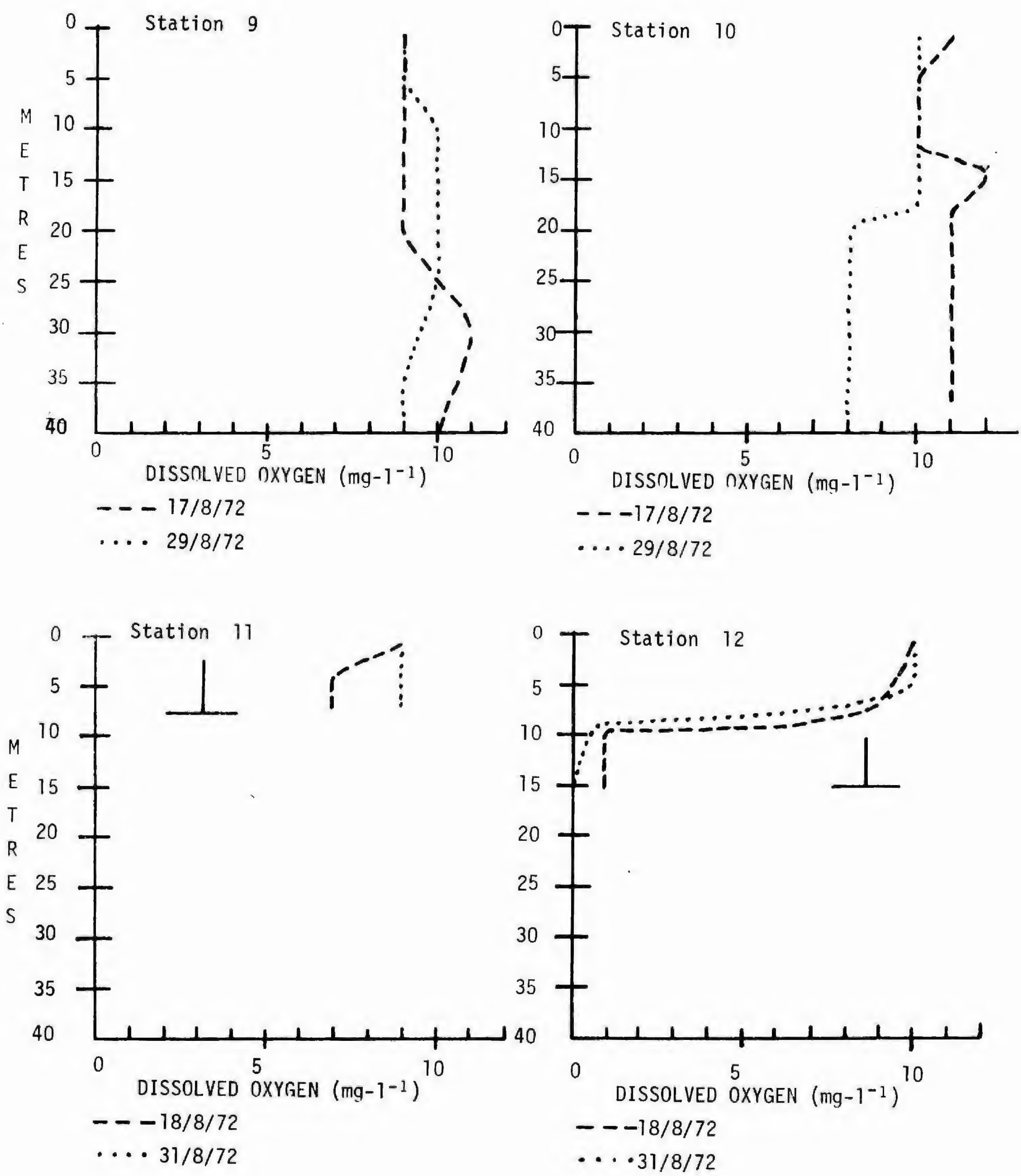
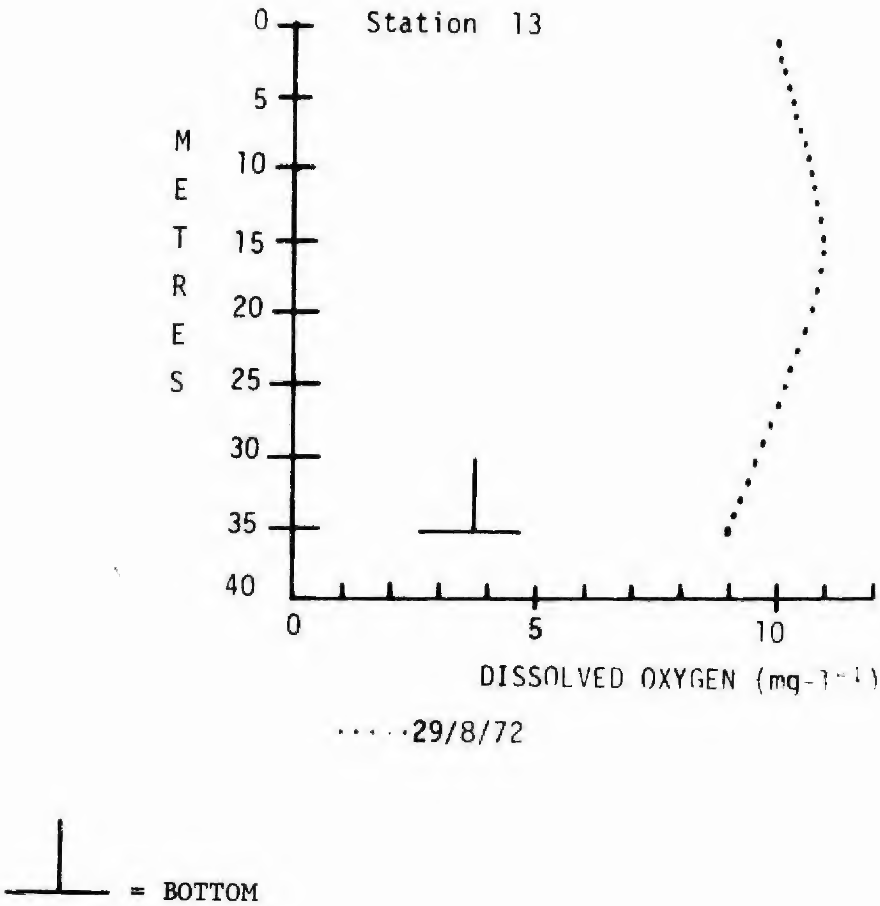


FIGURE 3.5.2 - continued



4.0 DISCUSSION

4.1 General Water Quality

Lake Temagami exhibited the low chemical concentrations typical of oligotrophic Precambrian Shield lakes. Table 4.1.1 is a comparative summary of lake water quality for various Precambrian Shield lakes including Lake Temagami. As indicated in the table, Lake Temagami is similar to other dilute freshwater environments in Ontario.

Chemically, Lake Temagami is not a homogeneous body of water and a pattern of variability is evident particularly for the parameters conductivity, sulphate, nutrients and dissolved oxygen. The conductivity in the Northeast Arm (stations 1 and 2, 11 and 12) was high with a maximum of 156 μmho cm^{-1} at station 12. Stations in the "mid-lake" had conductivities ranging from 60 to 65 μmho cm^{-1} while stations in the northernmost portion of the lake (10 through 13) had values of less than 60 μmho cm^{-1} with a minimum reported value of 39 μmho cm^{-1} (station 13). The variability in conductivity was attributable for the most part to differences in the major anions, sulphate and bicarbonate (alkalinity), with alkalinity ranging from a low of 4 mg l^{-1} as $CaCO_3$ at station 13 to 29 mg l^{-1} as $CaCO_3$ at station 12. The range in sulphates for the same stations was 14 to 25 mg l^{-1} and calcium ranged from 5 to 15 mg l^{-1}. The lower pH at the northern end of the lake (6.5 to 6.8) is no doubt due to the lack of buffering at this station as indicated by the low alkalinity values.

TABLE 4.1.1

COMPOSITION OF DILUTE LAKE WATERS FOR SELECTED IONS

	SECCHI DISC	CONDUCTIVITY*	pH	TOTAL P $\mu g l^{-1}$	NO_3 $mg l^{-1}$	SULPHATE $mg l^{-1}$	SILICA $mg l^{-1}$	CALCIUM $mg l^{-1}$	ALKALINITY AS $CaCO_3$	REFERENCE
Temagami	4.6-11.9	39-156	6.0-7.4	1-68	>0.01-0.42	13-40	0.6-3.0	5-15	4-24	present study
Superior	10	79-90	7.4	>1		3.2	2.1	12.4	32	Beeton and Chandler 1967
Huron	9	192	8.1			9.7			50	Beeton and Chandler 1967
E.L.A.		19	5.6-6.7		>0.02	3	0.5	1.6	3.1	Armstrong and Schindler, 1971
Sudbury Lakes	5-12.0	52-80	5.0-7.8	>0.1-0.5	>0.1-1.25	7-23	0.14-16.7	0.6-13	1.54-28	Conroy, 1971

* Conductivity in μmho cm^{-1} @ 25°C

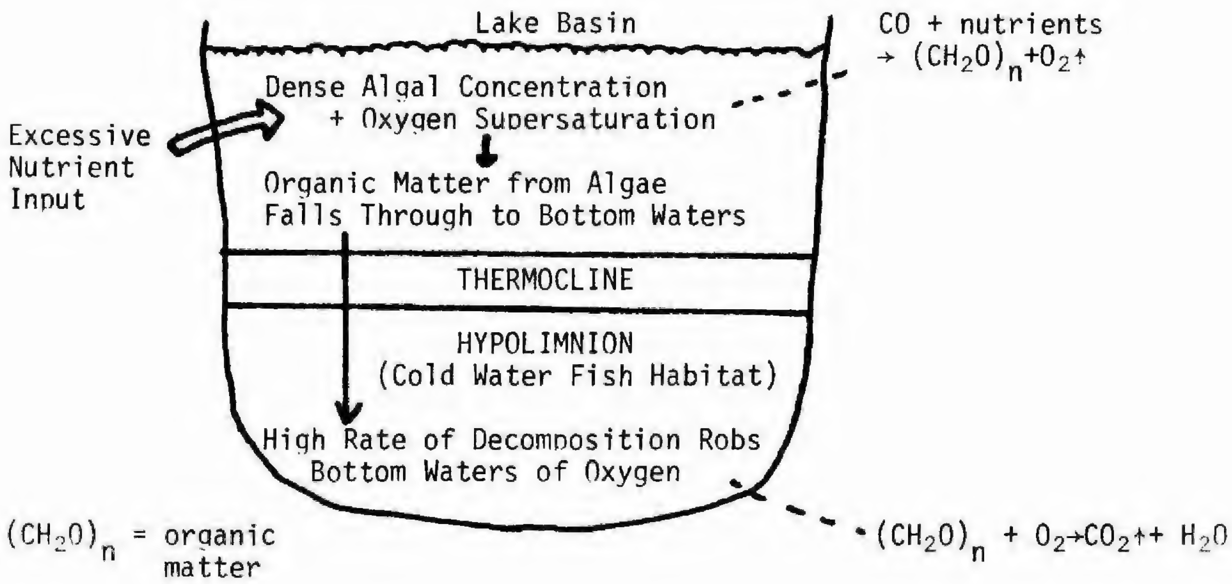
The high concentration of nutrients in the Northeast Arm (stations 1, 2, 11 and 12) reflects the effects of relatively intensive development. Dangerously high concentrations of phosphorus were noted at these stations (maximum of 0.11 mg l^{-1}). The concentrations were sufficiently elevated to promote intensive water blooms of blue-green algae as happened in 1966 and 1970. Also the nutrient additions were sufficient to cause reductions in dissolved oxygen to dangerously low levels in Portage Bay (vicinity of Temagami). When bottom water dissolved oxygen concentrations fall below approximately 4 mg l^{-1} the fish population is jeopardized since fish require oxygen for breathing. As noted in section 3.5, dangerously low levels of dissolved oxygen were recorded at stations 1 and 12. These results confirm the information provided in the sanitary surveys (Timiskaming Health Unit, 1967-68 and Ontario Water Resources Commission, 1967) that a significant organic loading from malfunctioning domestic sewage systems has gained access to the bay. The operating mechanism causing this oxygen deficiency is depicted in figure 4.1.1. The biological response to the addition of excessive nutrients to lake water from man's activity is referred to as cultural eutrophication. A more detailed description of the eutrophication process is provided in section 4.2.

Two additional concerns related to the water quality of Lake Temagami are acidification and the concentration of heavy metals. These are discussed below under separate headings.

FIGURE 4.1.1

SIMPLIFIED REPRESENTATION OF MECHANISM

CAUSING BOTTOM WATER DISSOLVED OXYGEN DEPLETION



Assessment of Acidification

The smelter gases from Sudbury contain large volumes of sulphur dioxide (SO_2) which, when oxidized in the presence of water produces sulphuric acid (H_2SO_4). With their inherently low buffering capacity, dilute Precambrian Shield lakes such as Lake Temagami are particularly susceptible to acidification by additions of atmospherically conveyed sulphuric acid. Lakes affected by acification typically become very unproductive (Johnson et al, 1970). As the hydrogen ion concentration increases (pH decreases) the biological activity decreases. The abundance and diversity of phytoplankton

and zooplankton (the base of the aquatic food web) appear to decrease and sensitive fish species fail to reproduce and are quickly lost from the system. As the pH continues to decline, more and more of the natural biota is destroyed and the water becomes progressively more transparent. In some cases (Jenson and Snekvik, 1972 and Beamish, 1970) entire fisheries have been destroyed by the effects of increased acidity.

pH (a measure of the hydrogen ion activity) provides an indication of the degree of lake acidification and it is recognized (O.W.R.C., 1970; Jenson and Snekvik, 1972) that declines in a fishery can be expected when the pH falls below 5.5. Further, there is evidence that pH's below 6.0 in combination with high concentrations of carbon dioxide can adversely affect certain species of trout (Lloyd and Jorden, 1964).

Where additions of sulphuric acid are responsible for increasing the acidity of lake water the mechanism of pH reduction involves a concomitant increase in the sulphate concentration. In lakes with a low buffering capacity a small increase in the sulphate concentration is sufficient to cause a significant elevation in the hydrogen ion concentration (pH depression).

The pH of Lake Temagami was generally within the Ministry's guideline of 6.5 to 8.5 considered essential for the protection of fish and other aquatic life. At certain stations (particularly those in the northern portion of the lake where alkalinity was low) pH's below 6.5 were recorded near the mud water interface where the production of organic acids from the decomposition of freshly sedimented material would be expected to cause a pH reduction.

Since, as already mentioned, sulphates did not correlate with low pH and, in fact, the strongest correlation was between high pH and high sulphates, the study has provided no evidence to suggest that the pH in Lake Temagami is being depressed by the Sudbury area mineral smelting industry. However, it is noteworthy that the sulphate concentration in the lake was relatively high. Although the concentration of sulphate may show considerable variation (Hutchinson, 1957) unpolluted, oligotrophic Precambrian Shield lakes normally contain less than 15 mg l^{-1}. Lake Temagami showed a mean concentration (considering all stations at all depths on all dates) of 19 mg l^{-1} and a modal (most frequently occurring) concentration of 17 mg l^{-1}. The source of sulphate to water is either the reaction of sulphur bearing minerals such as pyrite (FeS_2) or gypsum ($CaSO_4$) with water or atmospheric precipitation high in sulphur species. In a study by Conroy, 1971 it was found that the sulphate concentration in lake waters in an adjacent area of the Precambrian Shield was not strongly correlated with the presence of known sulphide bearing ore deposits. However, a positive correlation was found between the concentration of sulphate in the lake water and the wind vector distance from a major sulphide ore smelting industry.

It is entirely possible that sulphates in the form of atmospherically conveyed sulphuric acid are being added to Lake Temagami in small concentrations which are accumulating year by year and this acid may gradually use up the acid-buffering capacity of

the lake. This can occur since precipitation adds sulphates to the drainage basin while evaporation (the reverse mechanism) selectively removes only water thus allowing sulphuric acid to accumulate. In this regard, preliminary data on the pH and sulphate concentrations of precipitation from a monitoring station in the Northeast Arm of Lake Temagami are provided in Table 4.1.2 below.

TABLE 4.1.2

MEAN AND RANGE VALUES FOR pH AND SULPHATE CONCENTRATIONS IN PRECIPITATION-MONITORING STATION LOCATED IN THE VILLAGE OF TEMAGAMI

YEAR	pH			SULPHATE (mg l^{-1})		
	# of Samples	Mean	Range	# of Samples	Mean	Range
1970	6	4.1	3.9 - 4.4	4	4.2	.9 - 8.0
1971	11	4.4	3.4 - 5.5	12	8.2	1.0 -26.0
1972	11	5.0	4.3 - 6.7	12	5.2	.5 -14.0
Overall (1970 to 1972)	28	4.6	3.4 - 6.7	28	6.3	.5 -26.0

The U.S.A. average (Lodge et al, 1968) was 4.3 mg l^{-1} SO_4 while the mean concentration at Temagami was 6.3 mg l^{-1}. The mean value for 33 stations in Ontario biased toward the greater Sudbury area but including stations south of Lake Huron and northeast of Lake Superior was 6.8, indicating that the sulphate concentrations in the Temagami area is slightly less than this Ontario average but substantially higher than the reported continental U.S.A. mean concentration.

The average pH of precipitation in the Temagami area was 4.6 - lower than the lake water (pH = 6.9) and higher than predicted by the simple chemical reaction of sulphur dioxide and water: $SO_2 + \frac{1}{2}O_2 + H_2O \; SO_4 + 2H^+$. Assuming oxygen and water are in excess and that the reaction goes to completion, $SO_4 = 2H^+$ unless other chemical species are present to react with the sulphur dioxide and/or hydrogen ion. At SO_4 concentrations of 6.3 mg l^{-1} the predicted pH from the above equation is 3.9 while the measured pH is 4.6 indicating that a significant hydrogen ion sink is present in the rain and snow fall.

The rate of fall of sulphates on Lake Temagami (concentration x volume of precipitation) averaged approximately 1.08×10^{-5} gm cm^{-2} yr^{-1} for the 2½ years of the precipitation study. This provides an average addition of 2.21×10^4 kg SO_4 yr^{-1} or an effective yearly increment in the sulphate concentration in Lake Temagami (total fall divided by lake volume) of 5.5 μg l^{-1} yr^{-1}. This value is approximately 1/250 of the present lake water sulphate concentration and represents the minimum possible increment since the drainage basin could contribute precipitation with a similar concentration through runoff. However, only the surface area of the lake proper was used in the above calculation.

In summary, the proximity of Lake Temagami to the major mineral smelting industry (60 miles southwest) provides a potential for the acidification of the lake. However, the data provided herein suggest that Lake Temagami is not being adversely affected at this time, and information collected to date will serve as a substantial baseline with which to compare future data.

Heavy Metal Concentrations

Bearing in mind that any interpretation of the results of heavy metals analyses is difficult due to the lack of uniformity of detection limits in the chemical procedure, certain values for selected heavy metals approached or exceeded the values considered to exert either a direct lethal or an indirect sub-lethal effect on fishes. Table 4.1.3 provides a list of concentrations of metals considered potentially harmful to a fishery resource and the areas in Lake Temagami where these concentrations were approached or exceeded. A further comparative summary is provided in Table 4.1.4 indicating the accepted receiving water guidelines for selected heavy metals based on specific toxicity data and a suitable safety margin (for discussion see Ministry of the Environment, 1972).

Total copper exceeded the minimum threshold of 70 $\mu g\ l^{-1}$ at Station 7. On the 12th of August the copper concentration at this station was exceedingly high in the surface waters with a recorded value of 1200 $\mu g\ l^{-1}$ (sample contamination is suspected). The minimum threshold of toxicity for cadmium (20 $\mu g\ l^{-1}$) was exceeded at five stations (5, 6, 7, 9 and 10) on eight instances considering both time and depth. The concentration of zinc did not exceed the accepted minimum threshold for direct toxicity to fish, however, at station 7 a value of 670 $\mu g\ l^{-1}$ was recorded which approaches the lower limit of toxicity.

Concentrations of the remaining selected metals nickel, cobalt and arsenic (since arsenic concentrations were always less than 10 $\mu g\ l^{-1}$ values are not incorporated in the table) did not, at any time, approach the minimum threshold for toxicity. If the minimum threshold is substituted with a receiving water quality guideline as in Table 4.1.4 the suggested concentration of zinc

TABLE 4.1.3

COMPARISON OF ACCEPTED MINIMUM THRESHOLD FOR TOXICITY

WITH LAKE TEMAGAMI METAL CONCENTRATIONS

	*MINIMUM THRESHOLD ($\mu g\ l^{-1}$)	REMARKS	# OF STATIONS EXCEEDING	**TEMAGAMI STATION (see table 1.2.2)
Copper	70	96 hr TLm	1	Station 7 12/8/72
Zinc	780	96 hr TLm		Station 7 12/8/72 (value 670 approaching lower limit)
Nickel	4,000	96 hr TLm	0	
Cadmium	20	96 hr TLm	8	Stations 5,6,7,9,10
Cobalt	10,000	LC-50	0	

* from M.O.E., 1972

** station in Temagami approaching or exceeding minimum accepted threshold.

TABLE 4.1.4

COMPARISON OF ACCEPTED RECEIVING WATER GUIDELINES

WITH METAL CONCENTRATIONS FOR LAKE TEMAGAMI

	RECEIVING WATER GUIDELINE ($\mu g\ l^{-1}$)	NUMBER OF STATIONS EXCEEDING	TEMAGAMI STATION (see table 1.2.2)
Copper	30	1	7
Zinc	20	12	1,2,3,5,6,7
Nickel	400	0	
Cadmium*	--	--	
Cobalt	500	0	

* no receiving water quality guideline is provided for cadmium since it is assumed that any discharge of cadmium may be harmful since it is susceptible to biological accumulation.

($20\ \mu g\ l^{-1}$) is exceeded at 12 stations (considering both time and depth). Stations in the northeast and mid area of the lake, including stations 1, 2, 3, 5, 6 and 7 have recorded zinc values above the accepted receiving water quality guideline. The guideline for copper of $30\ \mu g\ l^{-1}$ was exceeded once at station 7, however as mentioned earlier, contamination of this sample is suspected. The concentrations of the remaining metals nickel, cobalt and arsenic are not considered to be problematic.

The effects of the metal concentrations approaching or exceeding the recommended receiving water guidelines or the minimum threshold of toxicity are unknown since the forms of the metals are not known nor is the specific susceptibility of Lake Temagami fishes to various metal concentrations known. In this regard, further work is necessary in the way of laboratory toxicity and bioassay studies of Lake Temagami and other Precambrian Shield waters. Also of concern is the concentration of these metals in the tissues of various fish species as a consequence of their inhabiting water with periodically high metal concentrations. Further work, in this regard, is being planned.

4.2 Trophic Status

It is possible to divide lakes in north temperate regions of the world into three integrading categories based on the extent of biological activity. Those lakes poorly supplied with nutrients and supporting meagre plant growth, considering both rooted aquatic plants and free floating algal forms, are termed oligotrophic. These lakes are generally deep, highly transparent and relatively unproductive. The deep waters remain well supplied with oxygen throughout the year. In oligotrophic lakes, fish species such as lake trout, whitefish and herring usually predominate.

Eutrophic lakes are on the other end of the scale; that is, they are richly supplied with nutrients and support heavy plant growth. The deeper waters of eutrophic lakes become depleted in oxygen owing to the decomposition of organic material. Normally, eutrophic lakes are turbid, warm and productive and game fish such as walleye, pike and perch predominate.

Lakes intermediate between oligotrophic and eutrophic are defined as mesotrophic. They have a moderate supply of nutrients and therefore moderate plant growth and a moderate degree of biological activity. As can be expected, often these lakes contain both warm and cold water species of fish.

From the water quality management point of view, oligotrophic lakes are most suited for water oriented recreational activities, including aesthetics, swimming, boating and angling for cold water fish species.

As indicated by Michalski and Conroy, 1972, "the most esteemed lakes for recreational development in Ontario are the deep, cold water, highly transparent lakes of the Precambrian Shield such as the Muskoka Lakes, Lakes of the Haliburton Highlands region and Lake Temagami". Eutrophic lakes are normally low quality recreational waters, not as highly esteemed for most water-oriented recreational activities.

On a geological time scale, lakes are considered to age. Lake ageing is the progression toward a eutrophic status. Further ageing causes lakes to become marshes and finally the marshes become dry land. This natural process is extremely slow - so slow that one would not normally measure a significant change in the trophic status of a lake in centuries of time.

Man's activity can cause lakes to age also, although there are fundamental differences between natural lake ageing and ageing through man's activity (see Beeton and Edmondson, 1972). As an overview, man's activity can amount to a greatly accelerated rate of eutrophication referred to as cultural or accelerated eutrophication. By using lakes as a sink for nutrient wastes generated from shoreline activity, man causes oligotrophic lakes (nutrient impoverished lakes) to become eutrophic (nutrient enriched lakes) in a very short period of time. As populations increase, evidence of culturally eutrophied lakes is becoming more evident (see Michalski and Conroy, 1972). It is apparent that culturally eutrophied lakes are least desirable from a recreational point of view and that emphasis should be placed on attempting to prevent lakes from being culturally eutrophied.

Research has shown (see Vallentyne, 1969) that lakes with Secchi disc transparency readings of less than 3 metres are eutrophic while lakes exhibiting Secchi disc transparency readings exceeding 6 metres are oligotrophic. Mean Secchi disc values from the open lake stations on Lake Temagami (1 to 10) ranged from 6.5 to 8.5 metres, indicating a highly oligotrophic status. Secchi disc values from stations 1 and 2 (mean values of 6.5 and 6.9 metres respectively) in the Northeast Arm, while still within the range considered typical of oligotrophic lakes, were considerably lower than the values at other stations and the overall mean value for the lake (7.7 metres). Single Secchi disc readings taken at stations 11 and 12 in Portage Bay, near the Village of Temagami were 3.8 and 4.2 metres respectively. The low Secchi disc readings at stations 11 and 12 are typical of a lake tending towards a eutrophic condition. The reduction in water clarity near the Village of Temagami no doubt reflects the input of nutrients from Temagami.

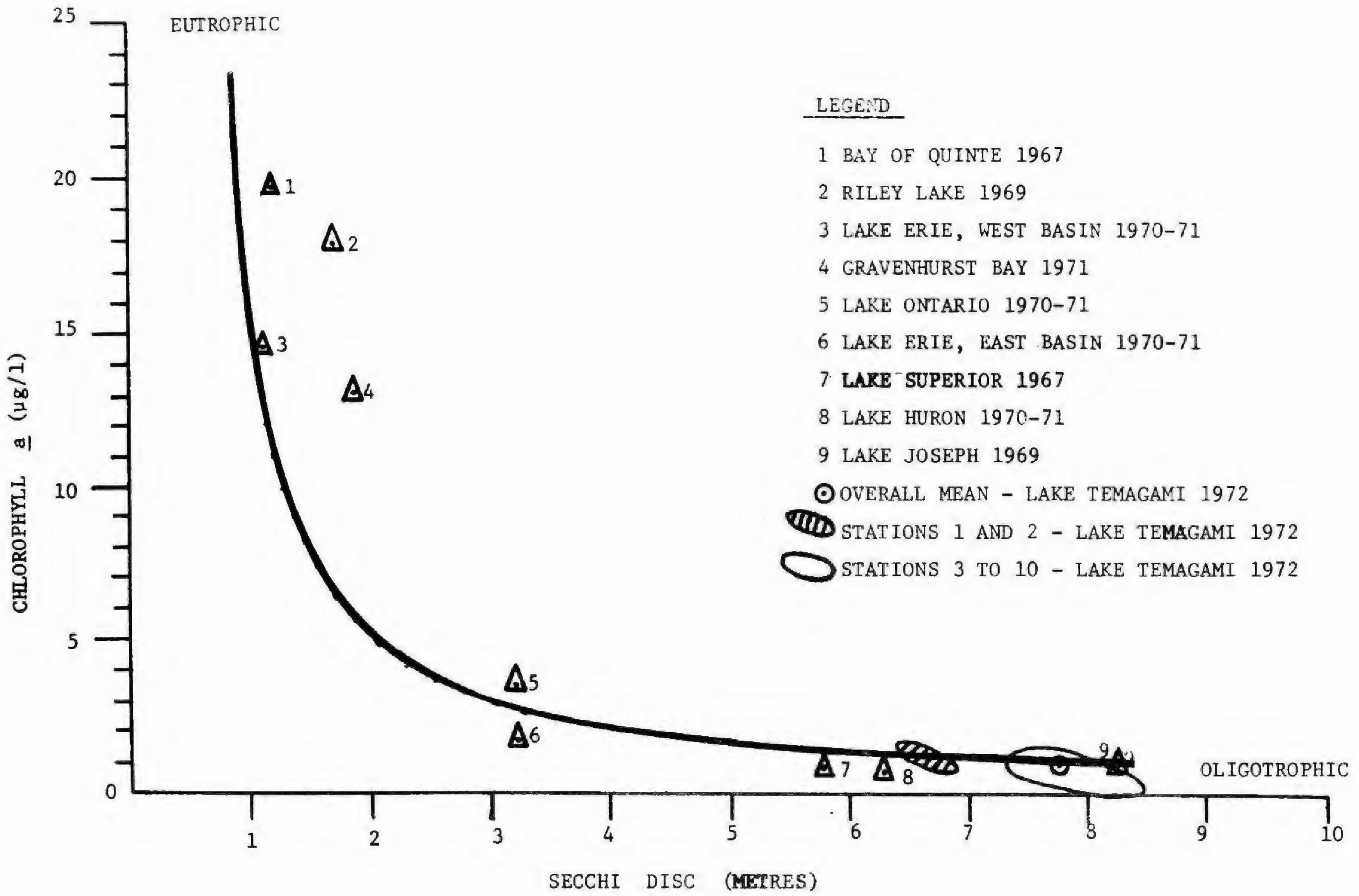
The concentration of chlorophyll a, the main photosynthetic green pigment in plants, can be used as an indication of the extent of biological activity in a lake at the time of sampling. Experience has indicated (Michalski and Conroy, 1972) that chlorophyll a values below 5 $\mu g\ l^{-1}$ indicate low to moderate algal densities characteristic of oligotrophic lakes, while concentrations greater than 10 $\mu g\ l^{-1}$ reflect high algal densities typical of eutrophic lakes.

Mean chlorophyll a concentrations in the open lake stations on Lake Temagami were very low ranging from 0.9 to 1.3 $\mu g\ l^{-1}$. As expected the lowest chlorophyll a concentrations corresponded to the highest Secchi disc transparency readings and vice-versa.

Brown, 1972, has indicated that a near hyperbolic relationship exists between chlorophyll a concentrations and Secchi disc readings, which can be used to bracket the trophic status of a lake. Figure 4.2.1 is a graph of this relationship with the values for Lake Temagami included. It is apparent from the graph that Lake Temagami is extremely oligotrophic. It is worth noting however, that stations 1 and 2 exhibit a tendency towards mesotrophy, that is, moving to the left on the horizontal axis of the graph, no doubt due to the influence of the intensive development in the Northeast Arm.

Further evidence of eutrophication in the Northeast Arm is provided by the critical levels of dissolved oxygen and the elevations of total phosphorus concentrations in this area. It has been indicated (see Michalski and Conroy, 1973) that troublesome levels of algae materialize in soft water Precambrian Shield lakes when mean total phosphorus concentrations during the ice free period exceed 20 $\mu g\ l^{-1}$. Mean total phosphorus values at station 1, 11 and 12 (34, 34 and 56 $\mu g\ l^{-1}$ respectively) in the Northeast Arm greatly exceeded this level. In this regard, in 1966 and again in 1970, reports of algae blooms in the Northeast Arm of Lake Temagami were received from the Ministry of Natural Resources. The relation between trophic status, dissolved oxygen and nutrients is described in section 4.1.

FIGURE 4.2.1 THE RELATIONSHIP BETWEEN CHLOROPHYLL a AND SECCHI DISC AS DETERMINED FROM ONTARIO LAKES.



4.3 Future Development

The land surrounding Lake Temagami and its islands is, for the most part, bare bedrock with a thin veneer of soils. Evidence in Ontario has shown that this type of terrain - the predominant land feature in the Precambrian Shield - does not lend itself to the conventional septic tank - tile field method of sewage treatment. In fact, in certain lakes in the Province (see Michalski, 1970; Schenk, 1971 and Michalski, 1971) where shoreline cottage density is high and conventional sewage disposal facilities have been employed, cultural eutrophication has occurred and has, to a degree, reduced the recreational potential of the waters. In addition, even in areas of sufficient soil depth in the Precambrian Shield it has been found that there is a limited capacity for these soils to assimilate the nutrients from sewage.

Owing to the unproductive nature of shield lakes, small additions of nutrients represent a significant increase in the total concentration of the lake water and can result in adverse changes such as algae blooms, bottom water dissolved oxygen depletion and taste and odour problems. Such water quality impairment is presently evident in the Northeast Arm near the Village of Temagami where development is more dense than on the rest of the lake and sanitary waste waters are flowing, untreated, or with relatively little treatment, directly into the lake.

In light of the already existing problems, as well as the susceptibility of Lake Temagami to small nutrient additions, any consideration for further development must provide for methods of

sewage treatment which eliminates or minimizes organic and nutrient loadings to the lake if water quality is to be protected. If safe systems are provided, pollution of the lake will not occur thus removing it as a constraint to development. There are, of course, other considerations for development which are beyond the context of this study that must be taken into account to ensure that optimum cottage densities are not exceeded (see Hough, Stansbury and Associates Ltd., 1971).

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W. Bradley and C. Lafrance, summer students with the Ministry of the Environment assisted in the collection of the intensive water quality information.

A P P E N D I X " A "

G L O S S A R Y

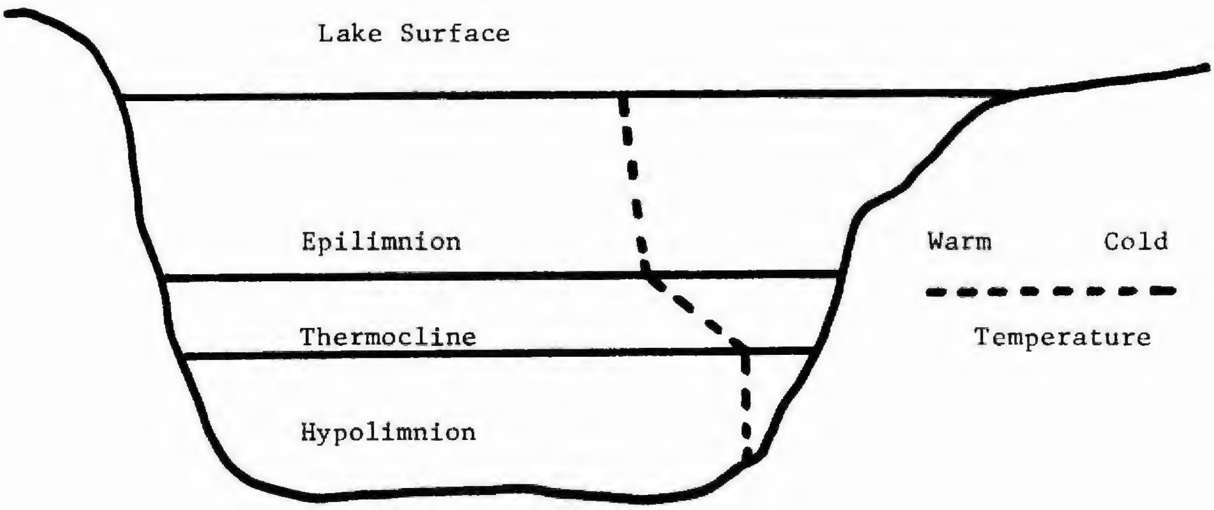
G L O S S A R Y

ACIDIFICATION - the process of becoming more acid - of increasing the hydrogen concentration. The standard measure of the hydrogen ion concentration is pH.

EPILIMNION - lakes which show thermal stratification have three distinct layers. The upper layer of water in which the temperature is relatively uniform is the epilimnion(see Figure A).

Figure A

Sketch of cross-section of theoretical lake during thermal stratification indicating water layers and temperature distribution.



EUPHOTIC ZONE - the intensity of light diminishes as it passes through water until at some depth there is insufficient light to carry on photosynthesis. This zone of significant light penetration is the euphotic zone.

EUTROPHIC - lakes are classified into three catagories on the basis of the biological activity - those with high biological activity and large nutrient concentrations are eutrophic. Characteristically eutrophic lakes are shallow, warm and highly turbid (see oligotrophic, mesotrophic and trophic status).

EUTROPHICATION - the process by which lakes become increasingly enriched in nutrients. It refers to the entire complex of changes which accompany nutrient enrichment including dense growth of algae and aquatic weeds.

HYPOLIMNION - the uniformly cold layer of water lying beneath the thermocline in thermally stratified lakes, see Figure A.

MESOTROPHIC - those lakes with a moderate supply of nutrients and moderate biological activity, i.e. a trophic status lying between oligotrophic and eutrophic.

OLIGOTROPHIC - lakes with a meagre supply of nutrients and low biological activity. Characteristically oligotrophic lakes are deep, cold water, highly transparent bodies of water.

pH - A measure of acidity/alkalinity on a scale from 0-14 where 7.0 is neutral and 6.9-0 indicates increasing acidity and 7.1 to 14 increasing alkalinity.

strongly acid	acid	neutral	basic	strongly basic
0-3.9	4-6.9	7.0	7.1-10	10.1-14

natural water

THERMOCLINE - the mid layer of water in thermally stratified bodies of water in which the rate of change of temperature is a maximum.

TROPHIC STATUS - lakes are classified on the basis of the degree of nutrient enrichment and biological activity into three integrating types; oligotrophic, mesotrophic and eutrophic. Additions of nutrients to infertile lakes (oligotrophic) tend to make them mesotrophic and with continued enrichment they will become eutrophic.

APPENDIX B

DATA TABLES

TABLE I

SECCHI DISC (METRES) AND CHLOROPHYLL a & b ($\mu g\ l^{-1}$) AT TEN STATIONS IN LAKE TEMAGAMI

SAMPLES WERE COLLECTED ON A WEEKLY BASIS MAY 31 - SEPTEMBER 19, 1972

DATE 1972	STATION 1 Chl a	& b	S.D.	STATION 2 Chl a	& b	S.D.	STATION 3 Chl a	& b	S.D.	STATION 4 Chl a	& b	S.D.	STATION 5 Chl a	& b	S.D.
May 31	1.2	0.1	5.8	1.2	0.1	6.1	1.2	0.3	7.6	0.8	--	9.7	0.9	0.3	9.1
June 7	0.9	--	6.7	0.6	0.3	6.7	0.8	0.2	7.6	0.9	0.1	9.1	0.8	--	10.7
June 13	0.7	0.1	7.9	0.8	0.2	8.5	0.7	--	9.1	0.8	0.1	8.2	0.8	--	9.1
June 21	0.8	0.2	6.4	0.7	0.3	6.7	1.0	0.4	6.7	1.1	0.4	7.6	0.8	--	8.5
June 28	0.5	0.2	8.5	0.4	0.1	9.1	0.5	0.2	9.7	0.4	0.1	9.4	0.4	0.1	9.1
July 5				0.8	0.1	7.9	0.7	0.3	8.2	0.8	--	8.5	0.9	0.2	9.1
July 13	1.0	0.2	7.0	0.9	--	6.7	1.0	--	7.9	1.0	--	7.9	1.0	--	8.5
July 26	1.0	1.0	7.6	1.0	1.0	7.0	1.0	1.0	7.6	1.0	1.0	7.6	1.0	1.0	8.5
August 2	2.2	0.1	6.1	2.3	0.3	6.4	1.3	0.1	6.4	1.6	0.3	4.6	1.3	0.2	6.7
August 8	1.9	--	7.0	1.7	--	7.0	1.5	0.1	8.8	1.2	--	8.5	1.1	--	8.8
August 16	0.9	0.1	6.4	0.9	0.1	6.4	0.9	--	7.6	1.0	0.1	7.6	1.0	--	6.7
August 23	1.0	0.1		1.1	0.2		1.3	0.3		1.0	0.1		1.0	0.1	
August 30	1.8	--	5.5	1.3	--	6.4	1.1	--	6.4	1.0	--	7.0	1.0	--	6.4
Sept. 6	2.3	0.2	6.7	1.4	0.2	7.9	1.7	0.2	7.6	1.2	0.3	7.9	1.0	0.4	10.4
Sept. 13	1.6	0.2	4.9	1.9	0.2	5.2	1.7	0.2	6.1	1.4	0.1	6.7	Broken		6.7
Sept. 19	2.4	0.2	5.2	2.3	0.2	5.5	1.9	0.1	6.1	2.0	--	5.2	1.6	0.3	6.4
Mean Values	1.3	0.2	6.5	1.2	0.2	6.9	1.1	0.2	7.6	1.1	0.2	7.7	0.9	0.2	8.3

TABLE I - continued

DATE 1972	STATION 6			STATION 7			STATION 8			STATION 9			STATION 10		
	Chl a	& b	S.D.	Chl a	& b	S.D.	Chl a	& b	S.D.	Chl a	& b	S.D.	Chl a	& b	S.D.
May 31	0.8	0.2	9.4	1.0	--	8.8	0.7	0.2	9.1	1.0	0.1	7.6	1.1	0.2	7.3
June 7	1.0	0.2	8.8	0.7	0.1	6.7	0.4	0.3	7.6	0.6	0.2	8.8	0.6	0.2	7.6
June 13	0.9	0.2	7.6	1.0	0.1	10.4	0.7	--	10.7	0.8	0.1	9.1	0.8	0.2	8.8
June 21	0.9	0.3	8.5	0.9	0.2	6.7	0.9	0.3	7.6	0.8	0.2	8.5	0.7	0.2	7.6
June 28	0.5	0.1	9.4	0.4	0.1	11.0	0.4	--	11.9	0.4	0.1	11.9	0.5	0.2	9.1
July 5	1.1	0.3	9.1	0.7	0.1	9.7	0.7	0.2	10.7	1.0	0.2	9.7	0.7	0.1	9.7
July 13	1.2	0.4	7.6	1.0	--	9.4	1.0	--	10.1	1.0	--	9.4	1.0	--	10.1
July 26	1.0	1.0	6.7	1.0	1.0	7.6	1.0	1.0	6.7	1.0	1.0	7.3	1.0	1.0	7.6
August 2	1.7	--	7.6	1.3	0.3	8.2	0.8	0.1	8.5	1.0	0.2	8.2	1.2	0.1	7.9
August 8	1.4	--	7.3	1.2	0.1	9.1	1.4	0.2	8.5	1.3	--	7.3	1.2	0.2	9.1
August 16	0.9	--	5.8	1.0	0.1	6.1	1.0	0.1	6.7	1.0	0.1	6.1	1.0	0.1	6.1
August 23	1.0	0.1		1.0	0.1		1.0	0.1		1.0	0.1		1.0	0.1	
August 30	1.2	--	6.1	1.0	0.2	6.1	1.0	--	6.7	1.0	--	6.7	1.0	--	6.1
Sept. 6	1.8	0.2	6.7	1.1	--	7.6	1.1	0.3	7.9	1.0	0.1	7.9	1.0	0.1	7.9
Sept. 13	1.3	0.1	4.9	1.6	0.1	6.1	1.4	0.3	6.4	1.0	0.2	7.3	1.0	0.1	5.5
Sept. 19	1.9	0.1	6.1	1.6	0.1	6.7	1.5	0.1	7.6	1.4	0.4	6.7	1.5	0.2	7.6
Mean Values	1.2	0.2	7.4	1.0	0.2	8.0	0.9	0.2	8.4	1.0	0.2	8.2	0.9	0.2	7.9

Overall mean -- Secchi disc -- 7.7 metres

Overall mean -- Chlorophyll a -- 1.1 μg^{-1}

TABLE II

pH AND CONDUCTIVITY VALUES FROM LAKE TEMAGAMI, AUGUST 11-31, 1972

DATA COLLECTED BY MINISTRY OF ENVIRONMENT

STATION	DATE	DEPTH	pH	CONDUCTIVITY	(μmho cm^{-1})
1	11/8/72	S	7.0	92.0	mean - 94
	11/8/72	B	6.8	95.5	
	31/8/72	S	7.2		
	31/8/72	B	6.9		
2	11/8/72	S	7.1	84.5	mean - 85
	11/8/72	B	6.8	85.0	
	31/8/72	S	7.2		
	31/8/72	B	7.1		
3	11/8/72	S	6.8	67.0	mean - 65.5
	11/8/72	B	6.7	64.0	
	15/8/72	S	6.9		
	15/8/72	B	6.9		
	31/8/72	S	6.6		
4	11/8/72	S	6.9	60.5	
	11/8/72	B	6.8	60.4	
	15/8/72	S	7.0		
	15/8/72	B	6.9		mean - 62
	30/8/72	S		63.0	
	30/8/72	B	6.2	64.0	
5	12/8/72	S	6.6	61.0	
	12/8/72	B	6.5	60.5	
	15/8/72	S	6.9		mean - 62
	15/8/72	B	6.4		
	30/8/72	S	6.7	64.0	
	30/8/72	B	6.3	65.0	
6	12/8/72	S	6.9	56.0	
	12/8/72	B	6.6	55.5	
	15/8/72	S	7.1		mean - 57
	15/8/72	B	6.4		
	30/8/72	S	6.4	56.0	
	30/8/72	B	6.1	62.0	

TABLE II - continued

STATION	DATE	DEPTH	pH	CONDUCTIVITY	(μmho cm^{-1})
7	12/8/72	S	7.1	59.5	
	12/8/72	B	6.8	58.5	
	17/8/72	S	7.8		mean - 60
	17/8/72	B	6.6		
	30/8/72	S		62.0	
	30/8/72	B	6.3	61.0	
8	17/8/72	S	6.9	58.0	
	17/8/72	B	6.3	57.0	mean - 58
	28/8/72	S	7.1	56.0	
	28/8/72	B	6.6	63.5	
9	17/8/72	S	6.7	56.5	
	17/8/72	B	6.8	55.0	mean - 57
	29/8/72	S	7.1	58.0	
	29/8/72	B	6.8	58.0	
10	17/8/72	S	6.5	57.0	
	17/8/72	B	6.3	56.0	mean - 56
	29/8/72	S	7.1	55.0	
	29/8/72	B	6.5	55.0	
11	18/8/72	S	7.0	102.0	mean - 105.5
	18/8/72	B	6.5	109.0	
	31/8/72	S	7.1		
	31/8/72	B	7.1		
12	18/8/72	S	8.3	100.0	mean - 128
	18/8/72	B	7.7	156.0	
	31/8/72	S	7.1		
	31/8/72	B	6.7		
13	29/8/72	S	6.8	39.0	mean - 40
	29/8/72	B	6.5	41.0	

Note: S - surface sample

B - bottom sample

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pH VALUES FROM LAKE TEMAGAMI, JULY 22 to SEPTEMBER 2, 1972

DATA COLLECTED BY TEMAGAMI LAKES ASSOCIATION

AND T.R.S.I.

STATION	DATE	DEPTH	pH (RANGE)	pH (MEAN)
1	30/7/72	S	7.7 - 7.8	7.8
	30/7/72	B	7.1 - 6.9	7.0
	12/8/72	S	7.3 - 7.4	7.4
	12/8/72	B	7.1 - 7.3	7.3
2	30/7/72	S		7.9
	30/7/72	B	7.6- 7.8	7.7
	30/7/72	S		7.2
	30/7/72	B	6.9 - 7.1	7.0
3	30/7/72	S	7.5 - 7.6	7.6
	30/7/72	B		6.7
4	2/8/72	S	7.5 - 7.6	7.6
	2/8/72	B	6.9 - 7.0	7.0
	2/9/72	S		7.2
	2/9/72	B	6.6 - 6.7	6.7
5	3/8/72	S	7.2 - 7.4	7.3
	3/8/72	B	6.9 - 7.2	7.1
	30/8/72	S	7.1 - 7.3	7.3
	30/8/72	B	6.6 - 6.7	6.7
6	24/7/72	S	7.0 - 7.1	7.1
	24/7/72	B		6.3
	9/8/72	S	7.0 - 7.2	7.1
	9/8/72	B	6.4 - 6.5	6.4
7	22/7/72	S		7.4
	22/7/72	B	6.9 to 7.0	7.0
	1/9/72	S		7.3
	1/9/72	B		6.9
8	3/8/72	S	7.2 - 7.5	7.2
	3/8/72	B	6.9 - 7.2	7.1
	31/8/72	S		6.7
	31/8/72	B	7.1 - 7.2	7.2

TABLE III (Cont.)

STATION	DATE	DEPTH	pH (RANGE)	pH (MEAN)
9	14/8/72	S	7.0 - 7.2	7.1
	14/8/72	B	6.6 - 6.2	6.6
	31/8/72	S	6.9 - 7.0	7.0
	31/8/72	B	6.4 - 7.0	6.6
10	25/7/72	S	7.0 - 7.2	7.1
	25/7/72	B	6.4 - 6.5	6.5
	15/8/72	S		7.0
13	25/7/72	S		6.4
	25/7/72	B	5.7 - 5.9	5.8
	14/8/72	S		6.2
	14/8/72	B		5.7
	31/8/72	S		6.0
	31/8/72	B		5.5
14 a	26/7/72		7.2 - 7.3	7.3
	12/8/72		7.3 - 7.4	7.4
14 b	26/7/72			7.3
	12/8/72		7.6 - 7.8	7.8
14 c	26/7/72		7.0 - 7.1	7.1
	30/7/72	all samples		7.4
	12/8/72	taken at .3m	7.4 - 7.6	7.6
		below surface		
15	26/7/72			6.7
	12/8/72		7.0 - 7.2	7.1
16	24/7/72		6.4 - 6.5	6.5
	9/8/72			7.0
17	24/7/72		6.6 - 6.7	6.7
	7/8/72			6.6
18	25/7/72		6.7 - 6.8	6.8
	29/7/72		6.9 - 7.2	7.1
	18/8/72		6.9 - 7.1	7.2
	20/8/72		6.9 - 7.0	7.0
19	3/8/72	S	6.8 - 6.9	6.9
	3/8/72	B		6.0
	17/8/72	S	6.9 - 7.0	6.9
	17/8/72	B	5.8 - 5.9	5.9
	31/8/72	S	6.5 - 6.6	6.6
	31/8/72	B		5.8

TABLE III (Cont.)

STATION	DATE	DEPTH	pH (RANGE)	pH (MEAN)
20	26/7/72	S	7.1 - 7.2	7.2
	26/7/72	B	6.4 - 6.5	6.5
	15/8/72	S	7.4 - 7.6	7.5
	15/8/72	B	6.8 - 6.9	6.8
21	24/7/72	S	7.3 - 7.4	7.4
	24/7/72	B		6.9
	7/8/72	S	7.1 - 7.2	7.1
	7/8/72	B	6.6 - 6.8	6.7
22	24/7/72	S		7.2
	30/8/72	S	7.0 - 7.2	7.2
23	3/8/72	S	7.1 - 7.2	7.2
	3/8/72	B	6.9 - 7.0	7.0
	2/9/72	B	6.5 - 6.6	6.6
24	25/7/72	S		6.6
	18/8/72	S	7.0 - 7.2	7.1
	19/8/72	S	7.0 - 7.1	7.1
	20/8/72	S	7.0 - 7.2	7.1

NOTE: S - Surface sample

B - Bottom sample

TABLE IV

DISSOLVED OXYGEN AND TEMPERATURE DATA

LAKE TEMAGAMI, 1972

STATION	DATE	DEPTH METRES	DISSOLVED OXYGEN mg l^{-1}	DISSOLVED OXYGEN % Saturation	Temperature °C
1	11/8/72	1.0	11	112	18.0
		2.0	12	128	18.0
		5.0	11	120	18.0
		7.0	10	116	18.0
		8.0	10	104	18.0
		9.0	9	93	17.0
		9.5	5	55	16.0
		10.0	3	30	15.5
	16/8/72	1.0	10	109	18.0
		5.0	10	107	17.0
		6.0	10	107	17.0
		7.0	9	97	17.0
		8.0	9	97	17.0
		9.0	1	.9	13.5
		10.0	1	.9	12.0
	31/8/72	1.0	8	90	19.9
		5.0	7	78	19.0
		7.0			18.2
		8.0			17.0
		9.0			16.5
		10.0	5	41	13.5
2	11/8/72	1.0	11	120	17.5
		3.0	11	120	17.5
		5.0	11	118	17.5
		9.0	9	103	17.5
		12.0	11	123	17.0
		13.0	10	103	15.0
		15.0	11	108	14.5
		18.0	10	98	14.0
	16/8/72	1.0	11	120	18.0
		4.0	10	115	18.0
		7.0	10	108	17.2
		12.0	10	107	17.0
		17.0	9	88	13.0
	31/8/72	1.0	8	90	19.0
		5.0			18.9
		10.0			17.0
		13.0			16.0
		15.0			13.0
		20.0			10.5
		25.0	6	54	9.2

TABLE IV - continued

STATION	DATE	DEPTH METRES	DISSOLVED OXYGEN mg l^{-1}	DISSOLVED OXYGEN % Saturation	TEMPERATURE °C
3	11/8/72	1.0	11	120	17.0
		4.0	11	120	17.0
		8.0	11	120	17.0
		10.0	11	122	16.0
		11.0	10	112	14.8
		12.0	11	108	14.0
		16.0	9	90	12.0
		20.0	8	80	11.0
		21.0	7	65	10.5
	15/8/72	1.0	9	98	18.0
		6.0	8	88	18.0
		10.0	7	73	15.1
		16.0	7	68	12.5
		20.0	8	75	10.8
	31/8/72	1.0	9	100	18.5
		5.0	9	99	18.1
		10.0	9	95	16.2
		13.0	8	82	14.9
		14.0			11.9
		15.0	7	65	10.6
		19.0	6	53	8.0
4	11/8/72	1.0	11	126	18.0
		5.0	12	124	17.0
		10.0	12	124	17.0
		15.0	12	126	16.5
		20.0	12	120	14.0
		24.0	11	108	12.0
		25.0	11	108	12.0
		30.0	11	108	11.0
		37.0	11	104	10.0
		40.0	11	102	9.8
		41.0	11	98	10.0
	15/8/72	1.0	9	98	18.0
		5.0	9	98	18.0
		8.0	9	98	18.0
		10.0	9	97	17.5
		11.0	9	95	15.6
		12.0	9	93	15.0
		15.0	9	89	13.0
		20.0	9	88	12.5
		25.0	8	77	12.0
		30.0	9	85	10.8
		35.0	8	74	10.0

TABLE IV - continued

STATION	DATE	DEPTH METRES	DISSOLVED OXYGEN mg l^{-1}	DISSOLVED OXYGEN % Saturation	TEMPERATURE °C
4	30/8/72	1.0	9	100	19.0
		5.0	9	100	19.0
		10.0	9	96	17.0
		13.0	9	95	16.0
		14.0	9	89	13.0
		15.0	9	87	12.1
		20.0	9	83	10.1
		25.0	9	80	9.0
		30.0	9	80	7.9
		35.0	9	76	6.5
		40.0	9	75	6.0
5	12/8/72	1.0	11	124	17.0
		3.0	11	124	17.0
		7.0	12	124	16.5
		12.0	12	125	15.5
		17.0	12	118	13.2
		22.0	11	112	12.5
		29.0	11	102	11.0
		32.0	10	98	11.0
	15/8/72	1.0	9	98	18.0
		5.0	9	96	17.0
		11.0	9	96	17.0
		12.0	9	91	14.2
		15.0	9	90	13.5
		18.0	9	88	12.5
		23.0	9	87	12.0
		28.0	9	85	11.2
	30/8/72	1.0	9	100	19.0
		5.0	9	100	19.0
		10.0	9	96	17.1
		15.0	9	89	13.0
		20.0	9	85	10.5
		25.0	9	83	10.0
		30.0	9	80	8.9
6	12/8/72	1.0	12	128	17.5
		4.0	12	128	18.0
		11.0	12	127	17.0
		12.0	11	117	16.0
		13.0	11	118	15.0
		14.0	11	113	15.0
		16.0	11	108	12.0
		21.0	10	94	10.0

TABLE IV - continued

STATION	DATE	DEPTH METRES	DISSOLVED OXYGEN mg l^{-1}	DISSOLVED OXYGEN % Saturation	TEMPERATURE °C
6	15/8/72	1.0	9	100	19.0
		3.0	9	98	18.0
		8.0	9	96	16.7
		13.0	9	90	14.0
		18.0	8	78	11.8
	30/8/72	1.0	9	100	19.0
		5.0	9	100	19.0
		10.0	9	96	17.0
		12.0	9	93	15.0
		14.0	9	87	12.0
		15.0	9	85	11.0
		20.0	9	78	7.6
7	12/8/72	1.0	12	130	17.0
		12.0	12	128	17.0
		14.0	12	126	17.0
		15.0	12	124	14.5
		20.0	12	114	12.0
		26.0	11	106	11.0
	17/8/72	1.0	9	96	17.0
		5.0	9	96	16.8
		15.0	10	99	13.0
		25.0	9	87	11.8
	30/8/72	1.0	10	111	19.0
		10.0	9	96	17.0
		12.0	9	93	15.0
		13.0	9	90	14.0
		14.0	9	88	12.5
		15.0	9	87	12.0
		20.0	9	85	11.0
		21.0	9	83	10.0
8	17/8/72	1.0	9	96	17.0
		4.0	9	96	17.0
		9.0	10	107	17.0
		14.0	10	99	13.0
		19.0	10	97	12.0
		24.0	9	85	11.3
		29.0	9	83	10.0
	28/8/72	1.0	10	111	18.9
		5.0	10	111	18.8
		10.0	10	109	17.5
		11.0	10	108	17.0
		12.0	10	104	15.0
		13.0	10	98	13.2

TABLE IV - continued

STATION	DATE	DEPTH METRES	DISSOLVED OXYGEN mgl^{-1}	% Saturation	TEMPERATURE °C
8	28/8/72	15.0	10	97	12.0
		20.0	10	93	10.2
		25.0	10	88	8.5
		30.0	10	85	7.0
9	17/8/72	1.0	9	96	17.1
		10.0	9	96	16.5
		15.0	9	90	13.8
		20.0	9	85	11.0
		30.0	11	102	10.2
		40.0	10	91	9.8
	29/8/72	1.0	9	100	19.0
		5.0	9	99	18.1
		10.0	10	105	16.2
		12.0	10	104	15.0
		15.0	10	97	12.0
		25.0	10	90	9.0
		35.0	9	78	7.2
		40.0	9	75	6.0
10	17/8/72	1.0	11	120	17.6
		5.0	10	108	17.2
		12.0	10	104	15.0
		14.0	12	118	13.0
		18.0	11	102	10.2
		22.0	11	99	9.0
		32.0	11	97	8.0
		37.0	11	95	7.8
	29/8/72	1.0	10	111	19.0
		5.0	10	109	18.0
		10.0	10	107	17.0
		12.0	10	104	15.1
		14.0	10	95	11.5
		15.0	10	92	10.0
		17.0	10	89	9.1
		20.0	8	68	7.0
		30.0	8	65	5.0
		40.0	8	64	4.8
11	18/8/72	1.0	9	99	18.0
		4.0	7	76	17.9
		7.0	7	76	17.8
	31/8/72	1.0	9	104	20.9
		5.0	9	100	19.0
		6.5	9	95	16.4

TABLE IV- continued

STATION	DATE	DEPTH METRES	DISSOLVED OXYGEN mg l^{-1}	% Saturation	TEMPERATURE °C
12	18/8/72	1.0	10	110	18.0
		7.0	9	98	17.5
		9.0	6	62	15.0
		10.0	1	10	14.8
		11.0	1	.9	11.2
		13.0	1	.9	9.5
		15.0	1	.8	8.5
	31/8/72	1.0	10	114	20.0
		5.0	10	114	20.0
		7.0	8	88	17.8
		9.0	0.9	.9	14.9
		10.0	0.7	.6	10.5
		12.0			7.5
		13.0			6.9
		15.0			4.8
13	29/8/72	1.0	10	111	19.0
		5.0			18.8
		10.0			17.5
		11.0			17.0
		12.0			16.0
		13.0			13.9
		15.0	11	105	12.0
		16.0			9.0
		17.0			8.0
		18.0			7.0
		20.0			6.4
		30.0			5.0
		35.0	9	72	4.4

TABLE V

RESULTS OF CHEMICAL ANALYSES OF WATER, LAKE TEMAGAMI, 1972.

STATION	DATE	DEPTH	Ca	Na	K	Mg	SiO_2	SO_4	NITROGEN				PHOSPHORUS		HARD	ALK.	CARBON	
									NH_3	Kjel	NO_2	NO_3	Tot.	Sol.			Org.	Inorg.
1	11/8/72	S	13	3	1.0		1.0	21	.03	.37	.004	<.01	.040	.008	40	20	9	3
	11/8/72	B	14	3	1.0		1.0	17	.05	.59	.004	.02	.068	.010	44	20	7	5
	31/8/72	S	11	3	0.6	4	0.6	18	.01	.19	.004	<.01	.013	.004		21	6	5
	31/8/72	B	11	2	0.6	4	0.7	16	.02	.31	.004	.006	.015	.004		20	6	5
2	11/8/72	S	12	2	0.9		0.7	17	.02	.22	.003	.01	.006	.001	44	16	8	3
	11/8/72	B	11	2	0.9		1.0	18	.02	.19	.004	.06	.008	.002	43	16	6	4
3	11/8/72	S	7	1	0.4		0.9	17	.02	.25	.003	.01	.008	.001	32	12	7	2
	11/8/72	B	10	1	0.3		1.2	13	.04	.23	.004	.08	.012	.001	31	12	8	3
4	11/8/72	S	10	1	0.3		0.8	13	.02	.19	.002	.01	.008	.001	40	12	7	2
	11/8/72	B	10	1	0.4		1.0	13	.02	.18	.004	.04	.008	.001	38	12	7	3
	30/8/72	S	8	1	0.3	1	1.5	17	.02	.18	.004	<.01	.008	.006		13	6	1
	30/8/72	B	8	1	0.3	2	1.6	17	.01	.16	.003	.08	.007	.002		13	6	1
5	12/8/72	S	8	1	0.4		2.0	13	.02	.20	.003	.01	.008	.001	30	10	7	3
	12/8/72	B	10	1	0.3		2.0	13	.02	.16	.002	.04	.008	.001	25	10	6	3
	30/8/72	S	8	1	0.3	2	1.3	19	.01	.20	.004	<.01	.007	.006		16	6	1
	30/8/72	B	8	1	0.3	2	1.4	17	.01	.19	.004	.09	.006	.002		12	6	1
6	12/8/72	S	7	1	0.1		1.9	13	.02	.22	.004	.02	.010	.001	22	10	6	2
	12/8/72	B	7	1	0.1		2.6	13	.01	.23	.002	.09	.030	.002	23	10	6	3
	30/8/72	S	15	1	0.2	<1	1.2	17	.02	.18	.003	<.01	.007	.006		11		
	30/8/72	B	15	1	0.2	<1	1.6	17	.01	.15	.003	.08	.011	.010		8		
7	12/8/72	S	7	1	0.1			15	.02	.35	.004	.02	.026	.001	26	12	6	2
	12/8/72	B	7	2	0.2			15	.01	.22	.004	.06	.010	.002	25	10	6	2
	30/8/72	S	8	1	0.3	1.8	1	18	.02	.18	.004	<.01	.006	.004		12		
	30/8/72	B	8	2	0.3	1.6	<1	17	.02	.14	.004	.05	.006	.005		15		

TABLE V - (Continued)

STATION	DATE	DEPTH	Ca	Na	K	Mg	SiO_2	SO_4	NITROGEN NH_3	Kjel	NO_2	NO_3	PHOSPHORUS Tot.	Sol.	HARD	ALK.	CARBON Org.	Inorg.
8	17/8/72	S	10	1	0.3			16	.02	.21	.003	.02	.001	.010	31	15	5	3
	17/8/72	B	11	1	0.3		1.1	40	.02	.28	.004	.12	.018	.004	29	15	5	3
	29/8/72	S	8	1	0.3	7	1.5	17	.01	.28	.002	.02	.019	.002		11		
	29/8/72	B	8	1	0.3	5	1.7	16	.01	.16	.003	.06	.006	.003		12		
9	17/8/72	S	8	1	0.3		1.3	25	.02	.19	.003	<.01	.015	.003	32	14	4	3
	17/8/72	B	9	1	0.3		1.5	15	.02	.16	.004	.10	.006	.002	32	13	4	3
	29/8/72	S	7	1	0.2	2	1.4	16	.02	.19	.003	<.01	.006	.002		11		
	29/8/72	B	7	1	0.2	2	2.0	16	.01	.15	.003	.06	.019	.004		10		
10	17/8/72	S	8	<1	0.2		1.1	16	.02	.18	.003	.02	.005	.002	32	10	2	2
	17/8/72	B	8	<1	<0.1		1.9	14	.02	.15	.004	.10	.008	.002	29	10	2	2
	29/8/72	S	9	1	0.2	2	1.8	16	.03	.28	.003	<.01	.006	.002		11		
	29/8/72	B	7	1	0.2	5	3.0	14	.01	.18	.003	.08	.036	.002		12		
11	18/8/72	S	11	3	0.7		1.8	19	.05	.31	.005	<.01	.012	.004	36	21		
	18/8/72	B	12	3	0.8		1.3	19	.03	.46	.018	.02	.075	.012	36	22		
	31/8/72	S	12	3	0.7	3	0.7	20	.04	.33	.003	<.01	.020	.006		24	7	3
	31/8/72	B	12	4	0.8	2	0.9	19	.03	.28	.004	<.01	.028	.007		26	7	3
12	18/8/72	S	11	2	0.7		1.0	19	.04	.30	.004	<.01	.013	.004	35	22		
	18/8/72	B	14	7	0.7		2.4	16	.01	.43	.006	.42	.11	.032	44	29		
	31/8/72	S	12	3	0.5	2	2.2	17	.03	.31	.003	<.01	.012	.007		24		
	31/8/72	B	14	7	0.6	3	1.0	14	.35	1.0	.025	.015	.090	.017		24	9	5
13	29/8/72	S	5	1	0.2	<1	1.2	13	.03	.16	.003	<.01	.006	.002		4		
	29/8/72	B	5	1	0.3	1	1.4	14	.03	.17	.003	.03	.006	.004		4		

S = Surface Sample
B = Bottom Sample
All Values Expressed in mg l^{-1}

TABLE VI

RESULTS OF METALS ANALYSES ($\mu g\ l^{-1}$)

LAKE TEMAGAMI, 1972

STATION	DATE	DEPTH	COPPER	ZINC	NICKEL	CADMIUM	COBALT	ARSENIC	IRON
1	11/8/72	SURFACE	<50	50	<70				<50
	11/8/72	BOTTOM	<50	70	<70				65
	29/8/72	B	0.0	0.0	3	0.0		<10	100
2	11/8/72	S	<50	140	<70				<50
	11/8/72	B	<50	70	<70				<50
	29/8/72	S	0.0	3	3	0.0		<10	44
	29/8/72	B	0.0	0.0	4	0.0		<10	31
3	11/8/72	S	<50	50	73				<50
	11/8/72	B	<50	20	<70				<50
	29/8/72	S	0.0	13	2	0.0		<10	22
	29/8/72	B	12	79	1	1		<10	28
4	11/8/72	S	<50	20	<70				<50
	11/8/72	B	<50	20	<70				<50
	30/8/72	S	0.0	0.0	3	0.0		<10	21
	30/8/72	B	24	<1	2	0.0		<10	24
5	12/8/72	S	<50	220	<70	100	<70	<10	<50
	12/8/72	B	<50	140	70	60	<70	<10	<50
	30/8/72	S	23	10	2	0.0		<10	245
	30/8/72	B	0.0	<1	4	0.0		<10	24
6	12/8/72	S	<50	160	70	80	<70	<10	<50
	12/8/72	B	<50	260	70	200	<70	<10	<50
	30/8/72	S	0.0	0.0	4	0.0		<10	20
	30/8/72	B	2	4	4	0.0		<10	41
7	12/8/72	S	1200	670	<70	<20	<70	<10	<50
	12/8/72	B	<50	190	<70	80	<70	<10	<50
	30/8/72	S	5	2	3	0.0		<10	50
	30/8/72	B	3	<1	4	0.0		<10	47
8	17/8/72	B	<30	20	40	10	<40	<10	<50
	29/8/72	S	0.0	5	1	<1		<10	5
	29/8/72	B	N.D.	6	2	N.D.			7
9	17/8/72	S	<30	10	40	20	<40	<10	<50
	17/8/72	B	<30	20	40	10	<40	<10	<50
	29/8/72	S	0.0	2	0.0	0.0		<10	12
	29/8/72	B	0.0	4	1	<1		<10	15
10	17/8/72	S	<30	20	40	20	<40	<10	50
	17/8/72	B	<30	20	40	20	<40	<10	<50
	29/8/72	S	0.0	3	1	<1		<10	24
	29/8/72	B	0.0	4	6	<1		<10	14
11	18/8/72	S	0.0	3	3	0.0	1	<10	<50
	18/8/72	B	3	11	4	0.0	6	<10	800
	29/8/72	S	0.0	2	3	0.0		<10	25
	29/8/72	B	0.0	5	2	0.0		<10	57
12	18/8/72	S	4	4	2	<1	4	<10	1200
	18/8/72	B	5	8	1	0.0	3	<10	1300
	29/8/72	S	0.0	0.0	4	0.0		<10	55
	29/8/72	B	0.0	4	2	0.0		<10	80
13	29/8/72	S	0.0	6	2	0.0		<10	16
	29/8/72	B	0.0	10	1	0.0		<10	16